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JOINT TREATMENT OF MUNICIPAL SEWAGE AND PULP MILL EFFLUENTS

Green Bay Metropolitan Sewerage District
Green Bay, Wisconsin

July 1970

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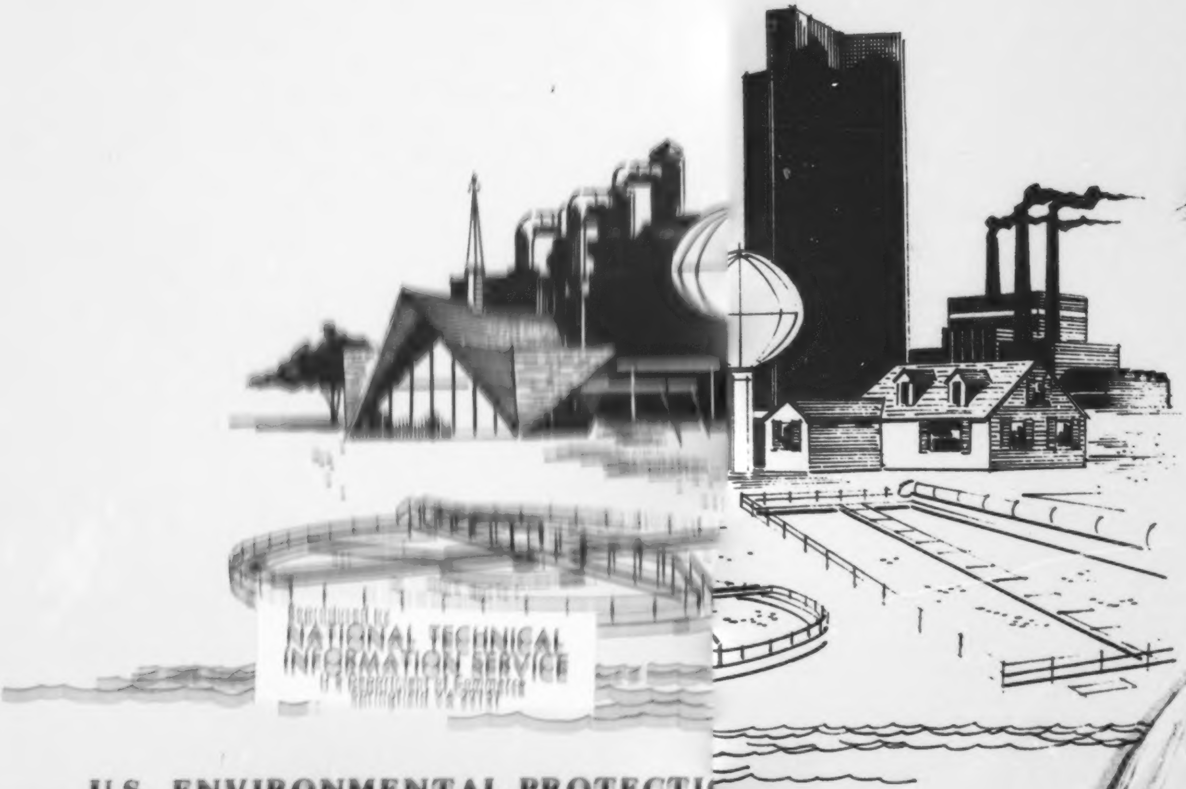
Joint Treatment
of
Municipal Sewage
and
Pulp Mill Effluents



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JOINT TREATMENT
OF
MUNICIPAL SEWAGE AND PULP MILL EFFLUENTS

by

The Green Bay Metropolitan Sewerage District
2231 Quincy Street
Green Bay, Wisconsin 54305

a report for the

ENVIRONMENTAL PROTECTION AGENCY

Program #12130 EDX
Grant #WPRD 60-01-67
July, 1970

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ABSTRACT

This research project determined the technical and economic feasibility of jointly treating the influent to the present treatment facilities of the Green Bay Metropolitan Sewerage District in combination with the weak effluents from the pulping sections of four local paper mills, specifically American Can Company, Charmin Paper Products Company, Fort Howard Paper Company and Green Bay Packaging, Inc.

Four activated sludge processes (conventional, step aeration, contact stabilization, and Kraus) were studied in parallel using 1-gpm pilot plants. At the end of the 12 months, the conventional and step aeration processes were eliminated from further consideration. The contact stabilization and Kraus processes were studied for an additional four and one-half months. Contact stabilization was selected as the most promising process and units were operated for an additional five months to obtain refined design and operating parameters for a full-scale treatment plant.

Shortly after initial start-up, the pilot plants became infested with filamentous organisms identified as a bacterial species of the genus Thiothrix, a sulfur-storing organism. Of various procedures implemented, chlorination of the return activated sludge successfully controlled the growth of filamentous organisms which caused sludge bulking. It was also necessary to add nutrients to achieve the desired BOD:N:P ratios.

The operation of the pilot plant units during the last study phase gave the following results:

BOD		TSS	
Primary Influent	- 478 mg/l	Primary Influent	- 224 mg/l
Final Effluent	- 43 mg/l	Final Effluent	- 50 mg/l
Percent Removal	- 91%	Percent Removal	- 78%

Extensive solids-handling unit process studies were conducted at the pilot plant site and in the cooperating manufacturer's laboratories.

The capital costs to the individual participants, based on becoming a part of the joint venture or providing separate facilities, are presented. American Can Company and Charmin Paper Products Company are joining with the Green Bay Metropolitan Sewerage District in a joint treatment plant program. Fort Howard Paper Company and Green Bay Packaging, Inc. have elected to provide their own facilities.

This report was submitted in fulfillment of Grant No. WPRD-60-01-67 between the Federal Water Quality Administration and the Green Bay Metropolitan Sewerage District.

Key Words: Joint Treatment - Weak Pulp Mill Effluent - Municipal Sewage - Pilot Plants - Activated Sludge - Filamentous Bacteria - Sludge Disposal - Capital Costs.

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CONCLUSIONS

The following major conclusions were reached during this research project:

1. A combination of weak pulping effluents from the ammonia base sulfite, calcium base sulfite, deinking, and neutral semichemical pulping processes can be successfully treated jointly with municipal sewage in an activated sludge treatment plant.

2. Activated sludge systems which incorporate reaeration of the return activated sludge are more stable in treating this particular combination of wastes. Of the four activated sludge processes studied (conventional, step aeration, contact stabilization, Kraus), the contact stabilization process proved to be the most successful in treating this particular combination of wastes.

3. Filamentous sulfide bacteria growth in the mixed liquor was successfully controlled by the continuous addition of 5-10 mg/l of chlorine to the return activated sludge. Low dissolved oxygen concentrations were not successful in controlling the filamentous sulfide bacteria. The addition of chlorine to the return activated sludge did not control non-filamentous bulking.

4. Nitrogen and phosphorus additions were required to achieve satisfactory biological operation. There was no advantage to adding the nutrients in the reaeration section as opposed to the contact section of the activated sludge process.

5. Satisfactory operation was achieved at dissolved oxygen levels between 0.5 and 1.5 mg/l.

6. It is more advantageous to bypass the mill effluents directly to the secondary treatment unit than provide primary clarification.

7. During a consecutive period of four and one-half months contact stabilization pilot plant operation, the BOD, TSS, and color removal averaged 91%, 78% and 19%, respectively. Increased TSS removals are expected in a full-scale final clarifier.

8. Total estimated costs for full-scale operation are as follows:

	CAPITAL	ANNUAL	
		O + M	Capital Invest
Joint Facilities	$31,127,000	$3,087,000	$3,705,000
Separate Facilities	37,796,000	4,496,000	4,496,000

RECOMMENDATIONS

The following recommendations for future research activities are made:

1. Determine the optimum quantity of nutrients to be added to maximize the process operation and minimize the quantity of nutrients discharged in the effluent. Satisfactory operation was maintained for extended periods at BOD: ortho phosphorus (as P) ratios of 100:0.5.

2. Determine the minimal amount of chlorine addition to the return activated sludge necessary to minimize the filamentous sulfide bacteria population in the activated sludge.

3. Determine an effective means of greater color reduction through the process.

4. Study the SVI test to determine the maximum permissible MLTSS to still obtain meaningful values of SVI.

5. Investigate the occurrence of poor effluent quality associated with poor settling, non-filamentous type activated sludge in relation to:

   a) BOD:N:P ratios
   b) return activated sludge chlorination rates
   c) high carbohydrate content in the influent sewage

INTRODUCTION

History

The Green Bay Metropolitan Sewerage District (GBMSD) is a separate and distinct municipal corporation created in accordance with Wisconsin State Statutes in December, 1931.(1) Early in the developing stages of the District, the following major policy decision was made with regard to the pulp and paper industry:

> As the integrated pulp and paper mills represented a large flow volume and since primary treatment of these effluents would produce little BOD reduction, it was mutually decided to omit all effluents from this industry except sanitary wastes generated by employees.

Interceptor sewers, a river crossing and a 9.0 MGD primary treatment plant were completed by 1937. A trickling filter plant was placed in operation in 1955.

In 1958, upon redefinition and enlargement of the policy decision regarding pulp and paper mill effluents, joint treatment studies were initiated between the Charmin Paper Products Company and the GBMSD. This marked the beginning of joint industrial-municipal treatment studies between the GBMSD and the pulp and paper industry of Green Bay.

The studies during 1958 and 1959 concerned evaluation of the treatability of Charmin yeast plant effluents with GBMSD (Metro) sewage using trickling filters. These studies indicated that the combined wastes required more filter capacity per pound of BOD removed than the municipal wastes alone; on this basis the concept was uneconomical and the studies were concluded at that time.

In 1964, joint treatment studies were again initiated between Charmin Paper Products Company and the Green Bay Metropolitan Sewerage District.(2,3) At that time the GBMSD was formulating plans for expansion and was considering the activated sludge process. Charmin desired to study the treatment of dilute effluents from their pulping processes and in-plant treatment systems. Therefore, laboratory studies utilizing 15-liter reactors were begun in 1964. These studies were expanded to a large-scale continuous-flow pilot plant study, utilizing a contact stabilization package plant, to determine the treatability of the combined wastes in a continuous-flow system. These studies were concluded in 1966.

The results of the studies between 1964 and 1966 showed that the combined wastes were amenable to biological treatment. However, the problem of separating the biological solids from the treated liquid due to filamentous organisms had to be solved before a full-scale plant could be built.

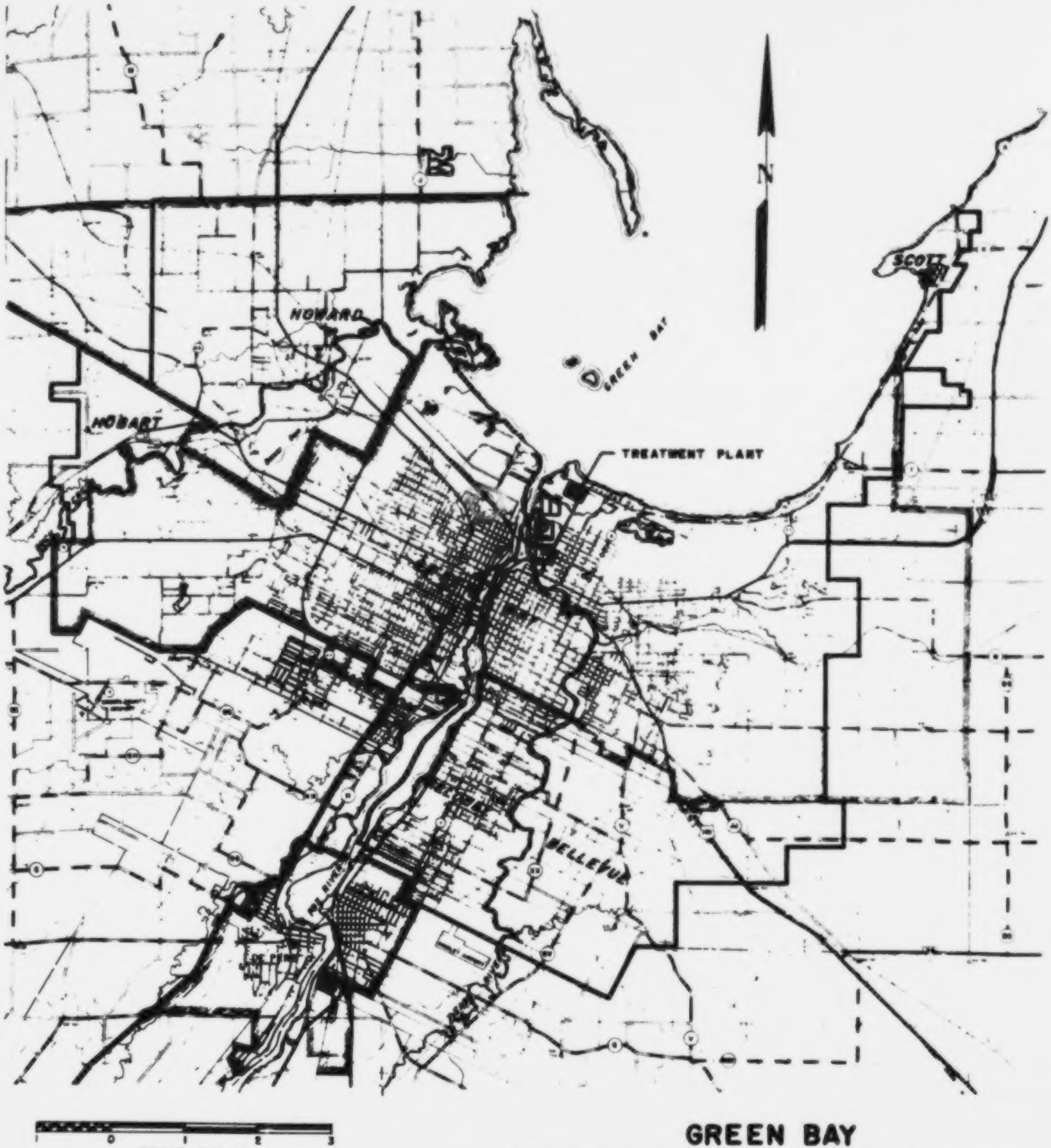
Realizing that additional studies were necessary to solve these problems and also recognizing that the three remaining major pulp and paper industries in Green Bay may be interested in a joint venture, the Green Bay Metropolitan Sewerage District invited American Can Company, Fort Howard Paper Company and Green Bay Packaging, Inc., to join with Charmin Paper Products Company and themselves in a joint industrial-municipal research project. The relative locations of the Mills and the existing sewage treatment plant are shown in Figure 1.

Present Research Program

Application was made by the GBMSD for a Research and Development Grant from the Federal Water Quality Administration, U.S. Department of the Interior; the GBMSD was awarded this grant in December, 1966. The total budget for the project was $335,000, of which 75% was funded by the FWQA and 25% was shared equally between the five participants.

The purpose of this research project was to determine the technical and economic feasibility of jointly treating the influent to the present treatment facilities of the GBMSD in combination with the weak effluents from the pulping sections of the four pulp mills.

The proposed research program was to study the four activated sludge processes (conventional, step aeration, contact stabilization and Kraus) simultaneously for twelve months in four 1-gpm pilot plants utilizing the combined wastes. During this time the effluent quality, operating parameters, design variables and cost relationships for each process would be established. At the end of the first year, the most promising process would be selected and studied in detail for a second year, during which time refined design, operating and cost parameters for the selected process would be obtained for a full-scale treatment plant.


N
HOWARD
HOBART
GREEN BAY
TREATMENT PLANT
SCOTT
BELLEVUE
1 0 1 2 3
SCALE IN MILES

GREEN BAY
METROPOLITAN SEWERAGE DISTRICT
SERVICE AREA

LEGEND

— DISTRICT LIMITS

1 GREEN BAY PACKAGING, INC.

2 CHARMIN PAPER PRODUCTS COMPANY

3 AMERICAN CAN COMPANY

4 FORT HOWARD PAPER COMPANY

WASTE CHARACTERISTICS AND JOINT TREATMENT OPTIONS

Detailed descriptions of the effluents from each pulp mill and GBMSD sewage are as follows:

American Can Company (Mill 1)
This is a calcium-base bisulfite pulping operation producing aspen pulp. The effluent stream consists of condensate from the liquor evaporation system which is composed mainly of acetic acid and some formic acid plus other miscellaneous volatile organic acids. It also contains the uncollectable liquors and effluent from chemical pulping and bleaching operations which contain carbohydrates and calcium lignosulfonates. The suspended solids are mainly fines and fibers from pulp washing operations.

Charmin Paper Products Co. (Mill 2)
This pulp mill uses the ammonia-base sulfite pulping process on regional hardwoods. The effluent is a composite of the dilute pulp wash waters and condensate from the liquor evaporator system. The BOD results primarily from volatile organic acids (acetic and formic) in the evaporator condensate. The balance is made up of carbohydrates and complex lignosulfonate compounds not collectable in the counter-current pulp washing system. The suspended solids are broken fibers, ray cells and other, almost collodial, solids that are not retained in the primary system of mechanical and flotation-type savealls.

Fort Howard Paper Co. (Mill 3)
The effluent from this plant consists of wastewaters collected from the de-inking of waste paper and excess white water from paper machines. The BOD is from the inks, starches, and other organics removed from paper that is subjected to the de-inking process. The suspended solids are the very fine clays and other filler materials from the de-inked paper along with some fiber fines. Since the effluent has already passed through primary treatment, only very fine or neutral buoyancy particles remain.

Green Bay Packaging, Inc. (Mill 4)
This company uses the neutral sulfite semi-chemical pulping process to manufacture unbleached board grade (high-yield) product. The effluent consists of the excess white water discharge from the paper making operation. The BOD loading is from spent neutral sulfite semi-chemical liquor which is not collectable in the pulp washing

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systems. The effluent contains dissolved sodium salts of complex lignosulfonic compounds together with smaller amounts of acetic, formic, and butyric sodium salts. The suspended solids are residual fibers not removed by drum filtration and flotation of the excess pulping and papermaking effluents. As such, the suspended material will range down to semi-collodial sizes.

Green Bay Metropolitan Sewerage District

The municipal sewage received at the treatment facilities is derived from five municipalities having a connected population of approximately 110,000 people and several wet industries composed of two large meat packing plants, two large vegetable canning operations, a pickle processing plant, a tomato canning operation, and various milk processing establishments.

The quantity and characteristics of each waste used for the final full-scale plant design are shown in Table 1. More complete data on the individual wastes are presented in Appendix C.

Joint Treatment Options

As shown in Figure 1, Mills 1, 2, and 4 are located near the GBMSD Treatment Plant while Mill 3 is located upstream approximately 3 1/2 miles. During the research project the assumption was that effluent from Mills 1, 2, and 4 would be conveyed to the treatment plant in a joint interceptor sewer constructed solely for that purpose. It was further assumed that an interceptor sewer would be constructed for Mill 3 effluent from the Mill site to a point approximately 1 mile from the treatment plant where it would discharge into the existing GBMSD interceptor sewer system.

In the initial planning of the project, major emphasis was placed on the assumption that all Mills would participate in the proposed full-scale joint treatment venture. Because of the costs for sewer construction, it was assumed that of the four mills, Mill 3 would be most likely to provide separate treatment facilities.

Treatment options studied were as follows:

Primary Clarification Studies

1. Each Mill alone.
2. Metro alone - average and simulated storm flow.
3. Mills 1, 2, and 4.
4. Mills 1, 2, 4 and Metro.

AVERAGE MILL AND METRO WASTE CHARACTERISTICS

UTILIZED FOR FINAL FULL-SCALE PLANT DESIGN

	Mill 1	Mill 2	Mill 3	Mill 4	Metro	Composite
Flow, MGD	5.0	5.0	13.25	0.6	30.0	53.85
BOD, mg/l	1440	720	600	2800	240	510
TSS, mg/l	240	100	120	1000	180	175
NH_3 as N, mg/l						19.4
Orthophosphorus as P, mg/l						1.6
pH						6.8

5. Mill 3 and Metro.
6. All Mills and Metro.
7. All Mills and Metro plus WAS return to Primary Clarifier.

Secondary Treatment Studies

1. Mills 1, 2, 4 and Metro - average flow*
2. Mills 1, 2, 4 and Metro - storm flow*
3. All Mills and Metro - average flow.

* Studies 1 and 2 were conducted with Metro only receiving primary clarification; Mills 1, 2, and 4 were sent directly to the secondary treatment unit.

SCHEDULE OF MAJOR EVENTS

The major events which occurred during the research project are summarized below to provide an overall view of the research schedule:

January 1 - June 1, 1967
Coordination and implementation of the grant award between the municipal and industrial participants.

June, 1967
Began laboratory reactor studies on a combination of proposed wastes to be fed to the pilot plants. Pilot plant design started.

August, 1967
Pilot plant construction began.

February 6, 1968
Started up pilot plants on Metro sewage.

February 27, 1968
Reached 100% feed of Metro and pulp mill wastes.

March, 1968
Aeration units became infested with filamentous organisms.

August, 1968
Concluded that the mixture of wastes was biologically treatable although the problem of separation of biological solids from the treated liquid still existed.

September, 1968 - January, 1969
Statistical experimental design conducted to assist in selection of the most desirable process.

January, 1969
Chlorination of return activated sludge appeared successful for controlling filamentous organisms.

February 1, 1969
Shut down pilot plants for cleaning and maintenance.

February, 1969
Conventional and step aeration units eliminated from further consideration. Studies continued on the contact stabilization and Kraus units.

February 24, 1969
Started up pilot plants on Metro sewage.

March 21, 1969
Reached 100% feed of Metro and pulp mill wastes.

April, 1969
Chlorination of return activated sludge proven effective in controlling filamentous organisms.

July, 1969
Contact stabilization unit selected as the most desirable unit.

September, 1969 - December 15, 1969
Extensive solids-handling unit process study conducted to gain information on the disposal of sludge produced from the contact stabilization process.

December 16, 1969
Pilot plants were shut down.

February 13, 1970
Presentation of the final cost estimate to the Steering Committee.

July 1, 1970
Termination date of the research project.

LABORATORY REACTOR STUDIES

Since there was no available information in the literature concerning the treatability of this particular combination of pulp mill effluents and municipal sewage, bench-scale laboratory reactors were operated to obtain preliminary information concerning BOD and TSS removals, nutrient requirements, potential filamentous microorganism bulking problems, required detention times, etc.

The "fill-and-draw" reactors utilized in this study were similar to glass carboys with the bottoms removed. The reactors were inverted and placed in a support stand. Two lines were marked around the circumference of each reactor; the top line indicated the total operating volume of the reactors; the bottom line indicated that volume of mixed liquor (return activated sludge, R) retained at each feeding. The volume between the two lines represented the volume of sewage (feed, Q) added at each "feeding". The recirculation ratio (R/Q) is the ratio of return activated sludge (R) retained to the feed (Q) added.

Each reactor was aerated for 5-1/2 hours after the addition of the feed. The aeration stone was then removed and the biological solids allowed to settle under quiescent conditions for one-half hour. The supernatant liquid was siphoned off until the liquid level reached the bottom line. A fresh batch of feed was then added and the aeration stone was replaced. Feeding times were 0400, 1000, 1600, and 2200. Once a day a calculated quantity of the reactor contents was withdrawn and wasted to maintain a relatively constant mixed liquor suspended solids concentration.

Laboratory analyses conducted on the final effluent were BOD, nitrogen (ammonia, total organic, nitrite, nitrate), ortho plus condensed phosphorus, pH and sludge volume index (SVI). Several of these analyses are a direct function of the suspended solids concentration in the samples and therefore are dependent not only on the quiescent-settling characteristics of the biological solids, but also on the degree of care exercised in removing the treated effluent. Therefore, a fill-and-draw reactor can be used primarily for studying the treatability of wastewater, whereas a continuous-flow reactor may also indicate potential problems due to poor sludge settleability.

On July 8, 1967, a 15-liter fill-and-draw reactor, R5, was started on Metro influent sewage. This sewage was settled for 10 minutes, a portion of the supernatant was decanted, mixed, sampled for laboratory analyses, and an appropriate amount then added to the reactor. Small quantities of each of the mill wastes were delivered to the GBMSD laboratory weekly. They were added in gradually increasing amounts to the Metro sewage, reaching 100% of the potential industrial feed by August 1. The summary of reactor operations is presented in Table 2. Average monthly operating data for R5 is presented in Table 3.

On August 11, a 5-liter reactor, R3, was started up to provide a reservoir of mixed liquor when poor mixed liquor settling properties developed in R5. The SVI in R5 had reached a high of 175 due possibly to the increased BOD to volatile suspended solids ratio (also known as food to microorganism ratio, or F/M ratio). R3 was started with waste activated sludge taken from R5, and was initially fed only Metro sewage. Average monthly operating data for R3 are presented in Table 4.

A second 5-liter reactor, R4, was started on August 25; it received the same feed as R5. It had an R/Q = 1.0 and was operated at a lower biological solids concentration resulting in a higher F/M ratio. Average monthly operating data for R4 are presented in Table 5.

Microscopic examinations were made on the reactors periodically. The microscopic structure and arrangement of mixed liquor solids (floc) differed greatly between the municipal-fed (R3) and the industrial-municipal fed (R4, R5) reactors. An unusual biological growth in the reactors was observed during August; lacking a positive identification, it was referred to as "coral". In February, 1968, it was identified as a "zoogleal" growth.

The return activated sludge volume of R5 was initially set at 5 liters, (R/Q = 0.5). However, due to the poor settleability of the mixed liquor solids, the clear supernatant volume after the one-half hour settling period was less than the volume of sewage to be fed to the reactor. Therefore, the recirculation ratio (R/Q) was then changed to 1.0, August 16, reducing the feed volume to 7.5 liters.

A dissolved oxygen (DO) analysis was made on R5 during August. After batch feeding of the unit, the DO remained at zero for a period of 15-30 minutes. The DO value then rose steadily until it reached 5-7 mg/l at the end of the 5-1/2 hour aeration period. This alternating aerobic-anaerobic condition did not have any apparent effect on the organisms. However, it may have been beneficial in reducing or eliminating certain varieties of filamentous organisms. This DO profile may also explain the previous experience of the GBMSD between 1964 and 1966, when superior results were achieved in fill-and-draw reactors as compared to continuous-flow pilot plants.

LABORATORY REACTOR STUDIES

Date	Reactor 3 (R3)	Reactor 4 (R4)	Reactor 5 (R5)
7/8/67			15-liter fill-and-draw reactor started on Metro sewage; R/Q = 0.5
8/1/67			100% Industrial plus Metro sewage feed reached
8/11/67	5-liter fill-and-draw reactor started on Metro sewage, using waste activated sludge from R5; R/Q = 0.5		
8/16/67			Changed R/Q to 1.0 due to poor settling sludge
8/23/67		5-liter fill-and-draw reactor started using waste activated sludge from R5; same feed as R5; R/Q = 1.0	
9/13/67		Began adding chlorine after each feeding. SVI is 70-80	SVI is 70-80
9/25/67		SVI is 50-60	SVI is over 100
10/13/67			SVI dropped below 100

Date	Reactor 3 (R3)	Reactor 4 (R4)	Reactor 5 (R5)
11/1/67	Reactor changed to contact stabilization unit; MLVSS and feed at one-half of R5 to obtain same F/M as R4 and R5		
11/16/67		Stopped chlorine feeding	Began feeding 2 mg/l Cl_2 after each feeding; SVI 69-123 between 11/1 and 11/16
11/29/67	Filaments first observed	No filaments	Filaments first observed
11/31/67		No change noted due to stopping Cl_2 addition	Final effluent more turbid since adding Cl_2; no major change in SVI between 11/16 and 11/30
12/2/67	No filaments		No filaments
12/21/67	Considerable number of filaments		
1/6/68			Stopped addition of Cl_2
1/13/68	Trace of filaments		No filaments
1/27/68			Filaments present
1/31/68	No filaments		Considerable number of filaments
2/10/68			Excessive number of filaments present, interfering with movement of protozoa
2/12/68			Began adding 3 mg/l Cl_2

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Table 2

Date	Reactor 3 (R3)	Reactor 4 (R4)	Reactor 5 (R5)
2/13/68	Considerable number of filaments	No filaments	
2/16/68			Increased Cl_2 dosage to 6 mg/l
2/17/68	Decrease in filaments		Increase in filaments
2/20/68	No mixed liquor settling problems. SVI average below 100		
2/21/68	1 liter of R5 mixed liquor added to increase filament concentration		
2/22/68	Increase in filaments	Filaments first observed	Increase in filaments
2/23/68	SVI = 400		
2/27/68	Excessive numbers of filaments present	Trace of filaments	Decrease in filaments, increase in larger, more desirable organisms. Added 30 mg/l of Cl_2 at 1600 feeding
2/28/68	SVI = 190, Reactor operation discontinued.	Reactor operation discontinued	Reactor operation discontinued

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R 5, 15-LITER REACTOR

Laboratory Data

		TSS, mg/l		%	BOD, mg/l		%	Aeration Unit		%	Wasted Sludge		Sludge	NH₃		T.O.		PHOS O&C AS P		pH		% Cell	BOD	F	Q
														AS NITROGEN											
		Inf	Eff	Red	Inf	Eff	Red	TSS	VSS	Vol	ml	SVI	Vol	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff	N	$\overline{NH_3}$	$\overline{M}$	L/D
7/67	Ave.	157	13	91.7	350	7	98.0	4449	3591	81.0	2247	255	55	11.6	0	12.0	2.9	6.0	2.49				30.7	.29	
	Max.	214	23	97.3	485	11	98.9	5520	4276	85.5	3500	290	64	15.5	0	17.0	4.4	8.7	8.7				51.9	.39	
	Min.	106	4	83.3	130	5	92.3	3836	3120	70.0	1000	200	47	6.8	0	7.2	1.3	.8	.14				12.4	.18	
8/67	Ave.	149	26	82.7	532	19	96.4	4631	4092	88.4	1426	600	129	17.6	5.7	10.9	5.3	4.7	.43			8.8	33	.29	
	Max.	192	314	98.3	708	136	98.7	5508	4940	91.2	3600	830	175	26.7	85.9	14.6	37.3	6.1	.79	7.5	8.2	9.8	66	.53	
	Min.	72	2	63.6	330	6	77.3	3848	3380	85.8	0	270	61	8.6	0	7.1	2.9	2.0	.10	6.1	7.5	6.7	19	.16	
9/67	Ave.	181	21	88.4	566	9	98.4	4742	4122	86.9	2018	485	100	24.3	3.3	12.8	5.0	5.0	.26			8.7	25.0	.28	29.8
	Max.	232	38	95.7	735	13	99.3	5632	4856	89.6	3500	780	148	34.9	10.6	17.6	8.3	6.2	.38	7.6	8.1	9.5	51.0	.37	30.0
	Min.	140	6	79.8	419	5	97.2	3972	3340	83.5	800	300	59	10.8	0	8.2	3.1	3.0	.14	6.5	7.3	6.4	13.0	.16	27.9
10/67	Ave.	203	32	84.1	564	17	96.9	4663	4059	87.1	2161	467	90	30.2	.1	12.6	7.5	5.2	.39			8.6	19	.28	30
	Max.	256	52	95.5	900	31	98.1	5448	4548	89.7	3000	410	123	37.3	3.6	15.1	12.5	6.8	.59	7.6	8.0	9.9	30	.43	30
	Min.	120	8	74.0	453	12	90.2	4232	3620	83.5	1000	260	69	24.3	0	7.7	4.5	2.6	.26	1.5	7.3	5.7	13	.12	30
11/67	Ave.	213	42	80.5	653	29	95.6	4678	4127	88.2	2397	419	92	23.3	0.8	13.4	7.1	4.6	.30			8.7	28	.32	30
	Max.	308	115	92.1	862	63	98.1	5820	5156	94.9	3500	630	132	31.9	6.0	18.9	12.5	6.0	.49	7.7	8.2	13.1	46	.42	30
	Min.	112	16	48.7	538	12	90.2	3760	3288	84.2	1500	320	64	16.5	0.0	8.4	4.5	2.3	.08	6.6	7.6	7.5	17	.24	30
12/67	Ave.	233	43	81.4	603	25	95.8	4520	4050	89.6	2558	417	127	23.2	3.7	14.1	5.6	4.8	.38			9.2	28	.30	30
	Max.	408	132	94.6	710	60	98.2	5128	4648	97.4	3400	620	184	34.8	12.2	19.7	7.5	6.3	.73	7.5	8.2	9.0	44	.36	30
	Min.	108	14	41.1	436	12	87.4	3420	3192	85.3	1500	300	64	14.2	0	9.2	4.0	1.2	.11	7.0	7.3	7.6	16	.22	30
	Ave.	262	31	88.2	592	18	96.9	4640	4000	86.2	2668	591	127	21.1	1.3	1.4	5.1	6.4	.4			8.3	29	.30	30
1/68	Max.	388	68	98.1	755	42	99.1	5528	4776	90.9	3600	860	184	26.0	9.1	19.7	12.3	9.2	1.7	8.2	8.5	9.6	37	.42	30
	Min.	136	4	73.5	258	5	93.9	3580	3020	81.6	1000	320	79	18.5	0	9.2	3.7	3.2	.18	3.3	7.4	6.4	15	.16	30
2/68	Ave.	251	34	86.5	586	19	96.8	3480	2962	85.1	417	832	243	23.2	3.9	12.9	5.7	5.0	.22	7.2	7.3	8.6	26	.20	15.9
	Max.	368	98	98.4	690	46	99.1	5304	4412	91.8	2700	970	330	26.1	11.6	15.3	9.2	6.7	.53	7.5	8.3	8.8	30	.39	30
	Min.	84	4	66.1	510	5	89.2	2428	2116	80.2	0	650	162	20.7	0	10.4	4.1	3.4	.11	6.8	7.4	8.3	22	.05	5.8

R3, 5-LITER REACTOR
Laboratory Data

Date		Aeration Unit			Wasted Sludge	Settled Sludge Volume	SVI	TSS, mg/l			BOD mg/l		
		TSS mg/l	VSS mg/l	% Vol.	ml	ml		Inf	Eff	% Red	Inf	Eff	% Red
9-67	Ave.	5203	4278	82.2	345	316	61						
	Max.	5564	5228	83.6	800	430	83						
	Min.	4888	3940	78.7	0	210	41						
10-67	Ave.	5258	4260	81.0	440	220	42						
	Max.	5956	4804	86.4	1000	260	50						
	Min.	4612	3820	78.8	0	190	37						
11-67	Ave.	2859	2504	87.6	1019	115	41						
	Max.	4916	3928	95.7	2500	215	50						
	Min.	1976	1892	79.7	300	90	25						
12-67	Ave.	2550	2293	89.9	950	189	75	261	58	77.8	649	48	92.6
	Max.	3148	2756	97.4	1500	270	112	408	132	88.0	710	72	96.1
	Min.	2160	1976	87.0	300	120	45	120	28	67.4	561	25	88.3
1-68	Ave.	2422	2118	87.4	731	195	82						
	Max.	3468	3240	93.4	1000	300	148						
	Min.	1892	1584	77.3	0	130	51						
2-68	Ave.	2515	2122	84.4	741	202	81						
	Max.	3492	2952	91.8	1200	400	115						
	Min.	1808	1536	76.4	0	140	55						

TSS - Total suspended solids
VSS - Volatile suspended solids

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R4, 5-LITER REACTOR
Laboratory Data

Date		Aeration Unit TSS mg/l	Aeration Unit VSS mg/l	Aeration Unit % Vol.	Wasted Sludge ml	Settled Sludge Volume ml	SVI	B.O.D. mg/l Inf.	B.O.D. mg/l Eff	B.O.D. mg/l % Red
9-67	Ave.	4662	4079	87.5	673	362	79			
	Max.	5836	5056	90.8	1500	720	146			
	Min.	4172	3440	85.0	400	185	47			
10-67	Ave.	4233	3689	87.2	750	219	52	587	18	96.8
	Max.	5152	4620	89.3	1000	265	68	900	30	98.0
	Min.	3792	3316	84.7	600	140	34	462	12	94.1
11-67	Ave.	4407	3863	87.7	925	233	54			
	Max.	7520	6704	93.9	1750	290	68			
	Min.	3660	3112	81.7	750	175	28			
12-67	Ave.	4157	3685	88.6	953	360	89			
	Max.	4956	4336	92.6	1150	700	179			
	Min.	3100	2480	80.0	450	170	37			
1-68	Ave.	4223	3695	87.5	1190	310	74			
	Max.	5895	5375	99.2	2300	890	237			
	Min.	2704	2308	81.5	0	180	51			
2-68	Ave.	4294	3653	85.1	1259	440	105			
	Max.	5620	4628	90.3	2000	820	229			
	Min.	2808	2384	79.9	700	270	55			

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Table 5

On November 16, the addition of 2 mg/l of chlorine to R5 with each feeding was started to determine the effect on SVI. Other than a noticeable increase in suspended solids in the final effluent, no significant changes were noted. Chlorination was discontinued January 6.

During February, phase-contrast microscopic analyses were made on a sample of mixed liquor from R5. These analyses showed that free sulfur and a filamentous sulfur bacteria, which utilized sulfides as an energy source, were present.

The problem of filaments and associated sludge bulking became quite severe during February. Since the mixed liquor solids did not settle to the desired level, the total amount of feed could not be added to the reactor. As a result, the biological solids production decreased and proper solids control could not be maintained. The F/M ratio dropped from a desirable 0.3 - 0.4 to as low as 0.09.

On February 12, chlorine was fed at 3 mg/l at each feeding in an attempt to improve the settling characteristics of the mixed liquor. By February 17 no visible improvements were observed, therefore, the chlorine dosage was increased to 6 mg/l. On February 27, the density of filaments in R5 had decreased, and larger, more desirable forms of microorganisms were observed in increasing numbers.

As R5 was to be discontinued on the 28th, it was decided to experiment with a stronger chlorine dosage. On February 27 a 30 mg/l dose of chlorine was added to the mixed liquor prior to shutting off the air for the one-half hour settling period. The supernatant liquor did not contain residual chlorine after the one-half hour period. The reactor contents were then siphoned off to the bottom line which permitted the full volume of feed to be added. In so doing, about 3-1/2 to 4 liters of activated sludge were wasted. Operators were then instructed to continue to draw off to the bottom line, even if it meant including solids in the final effluent, and to continue feeding the full volume of feed to maintain a 1:1 recirculation ratio. An improvement in the biological solids settleability was noted the same day.

The average R5 laboratory data for February are misleading as they indicate good BOD and suspended solids removals; however, had the required liquid volume been removed, rather than just the supernatant, the concentration of solids in the final effluent would have been substantial, resulting in laboratory data which would have shown poor performance of the reactor.

On November 1, R3, receiving municipal sewage only, was converted to the contact stabilization process, and began receiving the combined industrial-municipal feed. In order to maintain the same F/M ratio as R4 and R5, the mixed liquor solids concentration of R3 was reduced to 1/2 of the previous value and the unit was fed at alternate 6-hour periods. At the end of the first 5-1/2 hour period, the reactor contents were settled in the same manner as the other reactors and the supernatant was withdrawn. During the subsequent 6-hour period only the return activated sludge was aerated. At the end of this 6-hour period the feed was added to the reactor and again aerated for 5-1/2 hours. This cycle was continuously repeated thus simulating the contact stabilization process.

Although R3 did contain some filamentous organisms, settling problems did not occur during February. On February 21, 1 liter of R5 mixed liquor was added to R3 to purposely increase the filament population in an attempt to create poor settling conditions; an increase in the settled volume (to 400 ml) was recorded on February 23. However, by February 28, the settled volume had reduced to 190 ml which was within the normal range of prior operation. R3 was discontinued at that time. R4 was also discontinued February 28. Although this reactor did develop some filaments it did not have the severe problems that R5 experienced.

An extensive analysis of system performance was not conducted on the three reactors. The average values for mixed liquor total suspended solids (MLTSS), SVI, and BOD and total suspended solids (TSS) removals (excluding the February, 1968 data for R5 only) are as follows:

Reactor	MLTSS mg/l	SVI	BOD, mg/l			TSS, mg/l		
			In	Out	% Red	In	Out	% Red
R3	3468	64	649	48	92.6	261	58	77.8
R4	4329	76	587	18	96.8	---	--	----
R5	4618	99	551	18	96.9	200	30	85.3

This information confirms that this particular combination of pulp mill effluents and Metro sewage is biologically treatable in small laboratory reactors. However, the problem of filamentous organisms did occur which would make a continuous-flow plant inoperable. Therefore, the question of the treatability of this combination of effluents remained to be answered.

On February 28, two 5-liter reactors, R1P and R5P, were started up in the pilot plant room. R1P was fed Metro sewage only and was operated in the normal manner discussed for R5. The industrial-municipal feed to R5P was preaerated for 5-1/2 hours in an attempt to oxidize any sulfides present to a higher ionic form, thus inhibiting the growth of filamentous sulfur bacteria.

R5P was started up utilizing five liters of R5 mixed liquor. Improved settling of the biological solids was noted immediately upon startup as compared to the previous poor settling characteristics of R5. This immediate improvement could have been due to the 30 mg/l dosage of chlorine to R5, February 27, and not the preaeration of the feed to R5P. However, it was concluded that the continued good settling characteristics of the mixed liquor was attributable to the preaeration of the feed. The reactors were continued in operation through January, 1969.

The reactors were fed four times daily. Mixed liquor suspended solids analyses were made daily and wasting rates adjusted accordingly. The reactors operated quite well as compared to the pilot plants where problems were encountered due to poor sludge settleability. This confirms the fact that the treatability of a waste can be determined in a fill-and-draw reactor, but that the problems associated with the settleability of the sludge and resultant carry-over of solids can best be determined in a continuous-flow system.

The occurrence of filamentous organisms in the reactors was a prelude to the problems forthcoming in the operation of the pilot plants. The filamentous growth problems encountered in the pilot plant operation, the identification of the filaments, and the methods recommended for control of the filaments are discussed in detail in subsequent sections of this report.

PILOT PLANT DESIGN AND CONSTRUCTION

The location selected for the pilot plants was a storage area inside the Green Bay Metropolitan Sewerage District treatment plant. The room dimensions were approximately 22' x 44' in plan, and the clear height varied from 9' to 12'6".

During the previous research studies in 1966, a continuous plug-flow pilot plant was assembled utilizing six 55-gallon drums in series. However, because of space requirements and questionable mixing regimes, it was decided to construct rectangular tanks with large height to width ratios for this current research program.

The preliminary design of the pilot plants was based on the following parameters:

Total Flow to Four Pilot Plants, GPM:

Minimum - 2.85
Average - 4.00
Maximum - 5.72
The pulp mill component was assumed constant at 1.85 gpm.

Storage Tanks

Maximum design head room = 8'; maximize volume for floor area available.

Primary Clarifier

Overflow rate = 600 gpd/ft^2; detention time = 2 hours.

Aeration Tanks

Conventional, Step Aeration, Contact Stabilization

MLTSS = 3330 mg/l; 75% volatile solids content; return activated sludge (RAS) = 10,000 mg/l; R/Q = 0.5; detention time on conventional unit approximately 6 hours at maximum flow.

Kraus

MLTSS = 3380 mg/l; 70% volatile solids content; RAS = 10,000 mg/l; R/Q = 0.5; flow to nitrifying tank = 0.015 x average Q.

All Plants

F/M between 0.3 and 0.5 (BOD/MLVSS).

Final Clarifiers

Overflow rate approximately 500 gpd/ft^2; solids loading approximately 20 lb/ft^2/day.

Based on these parameters a 10-cell aeration tank (each cell = 1' x 1' x 7') was chosen for each plant. Removable, watertight baffles provided the necessary flexibility for volume changes.

An artist's rendition of the pilot plant facilities is presented in Figure 2. The floor plan and flow schematic are illustrated in Figures 3 and 4 respectively. An As-Built drawing is in Appendix A. Photographs of various items of the pilot plant are illustrated in Figures 5 through 6.

Fiberglass Mill Effluent Storage Tanks and Mixers

Boston motorized gear reducers, stainless steel shafts, and wooden paddles were used to construct mixers for the storage tanks. A nylon bearing support, which was molded into the bottom of the tank to support the mixer, gave excellent performance. There were no problems with the fiberglass tanks and mixing units during the 22 months of operation.

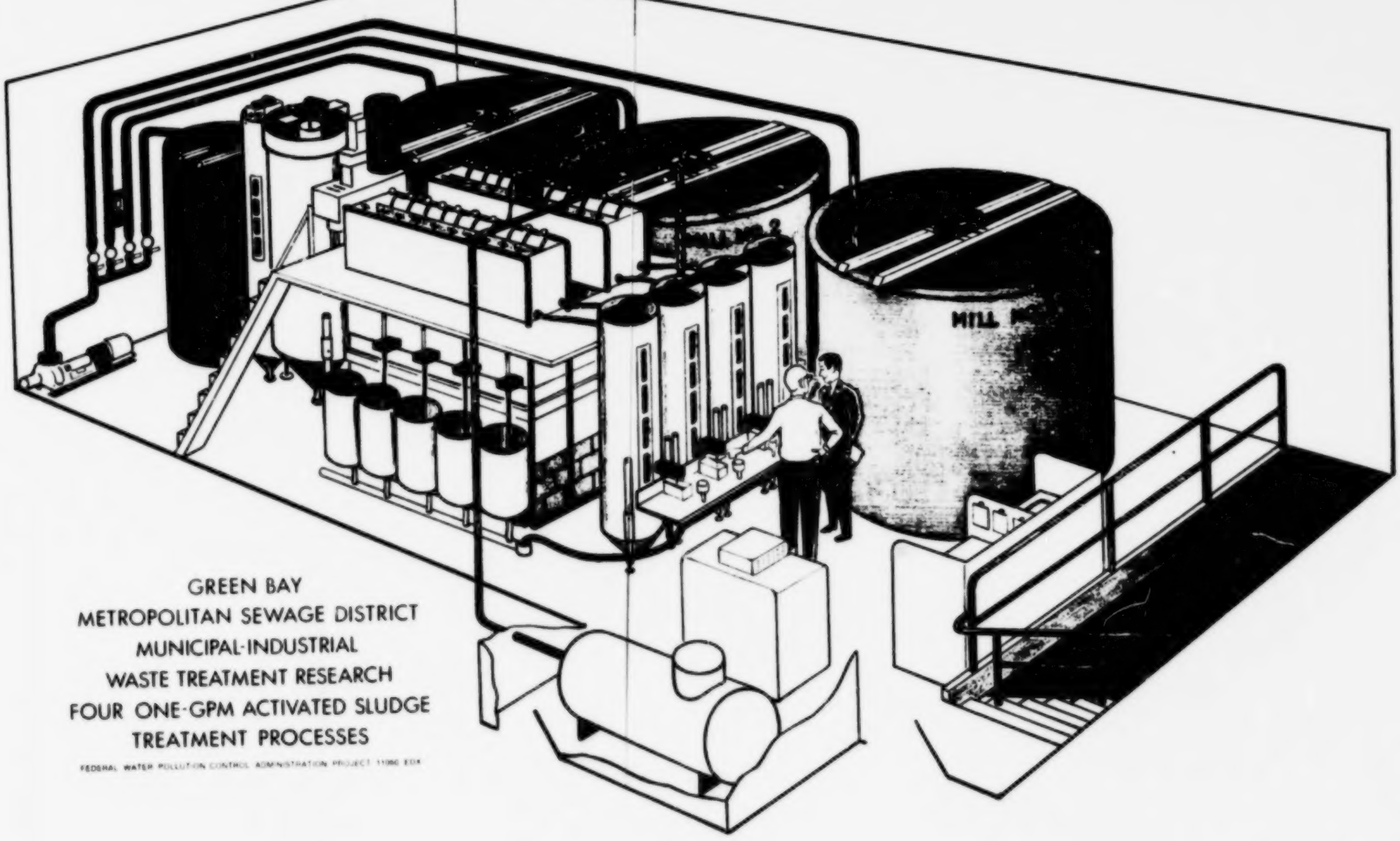
High-speed mixers were originally planned for the storage tanks. However, it was felt that excessive aeration would occur resulting in a change in waste characteristics.

Pumps

Three basic types of positive displacement pumps were used; Brosites 6-in-1 pumps, Jabsco flexible-impeller pumps, and Viking gear pumps. Three Model O Brosites pumps (500 mls/minute/tube maximum) and one Model OA Brosite pump (1000 mls/minute/tube maximum) were used in the pilot plant operations. The Model OA and two Model O pumps were used for mill waste pumping. The third Model O unit was utilized to pump miscellaneous flows such as nutrients, chlorine, digester supernatant and waste activated sludge.

Two sizes of Jabsco pumps were used; Model B-37 (3/8 inch) and Model JC (1/2 inch). The Model JC pump was utilized for variable speed pumping of Metro sewage from the grit chamber room to the pilot plant room. The Model B-37 Jabsco pumps were used for pumping return activated sludge from the final clarifiers to the aeration tanks.

As the Jabsco pump did not maintain consistent pumping rates when the RAS became quite concentrated, a Viking Gear Pump (Model FH 32, 1/2" suction and discharge, 3 gpm at 1800 RPM) was installed in place of one of the Jabsco pumps during the last 6 months of pilot plant operation.



GREEN BAY
METROPOLITAN SEWAGE DISTRICT
MUNICIPAL-INDUSTRIAL
WASTE TREATMENT RESEARCH
FOUR ONE-GPM ACTIVATED SLUDGE
TREATMENT PROCESSES

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION PROJECT 11060 EDX

PERSPECTIVE DRAWING OF PILOT PLANTS

FIGURE 2

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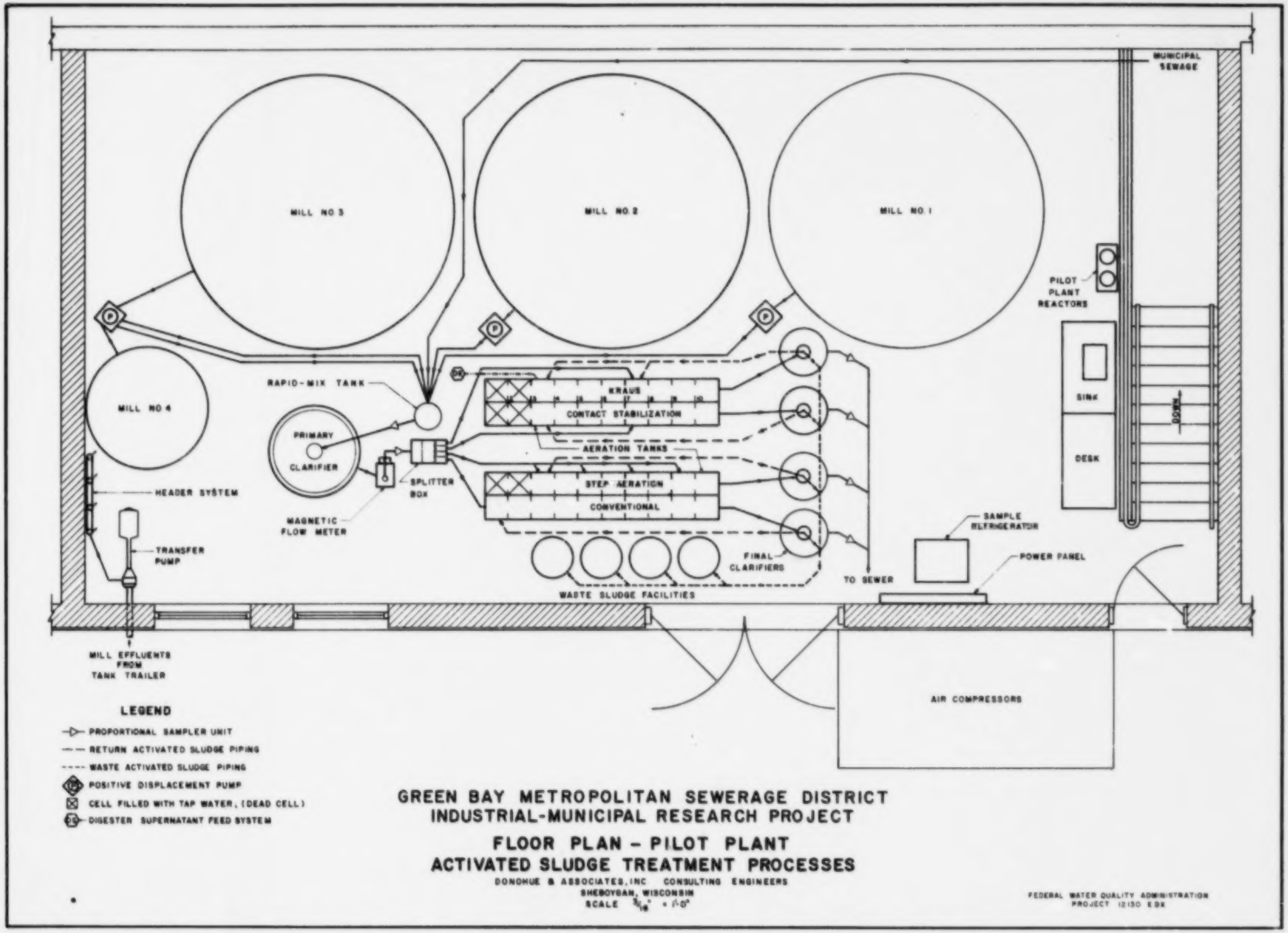
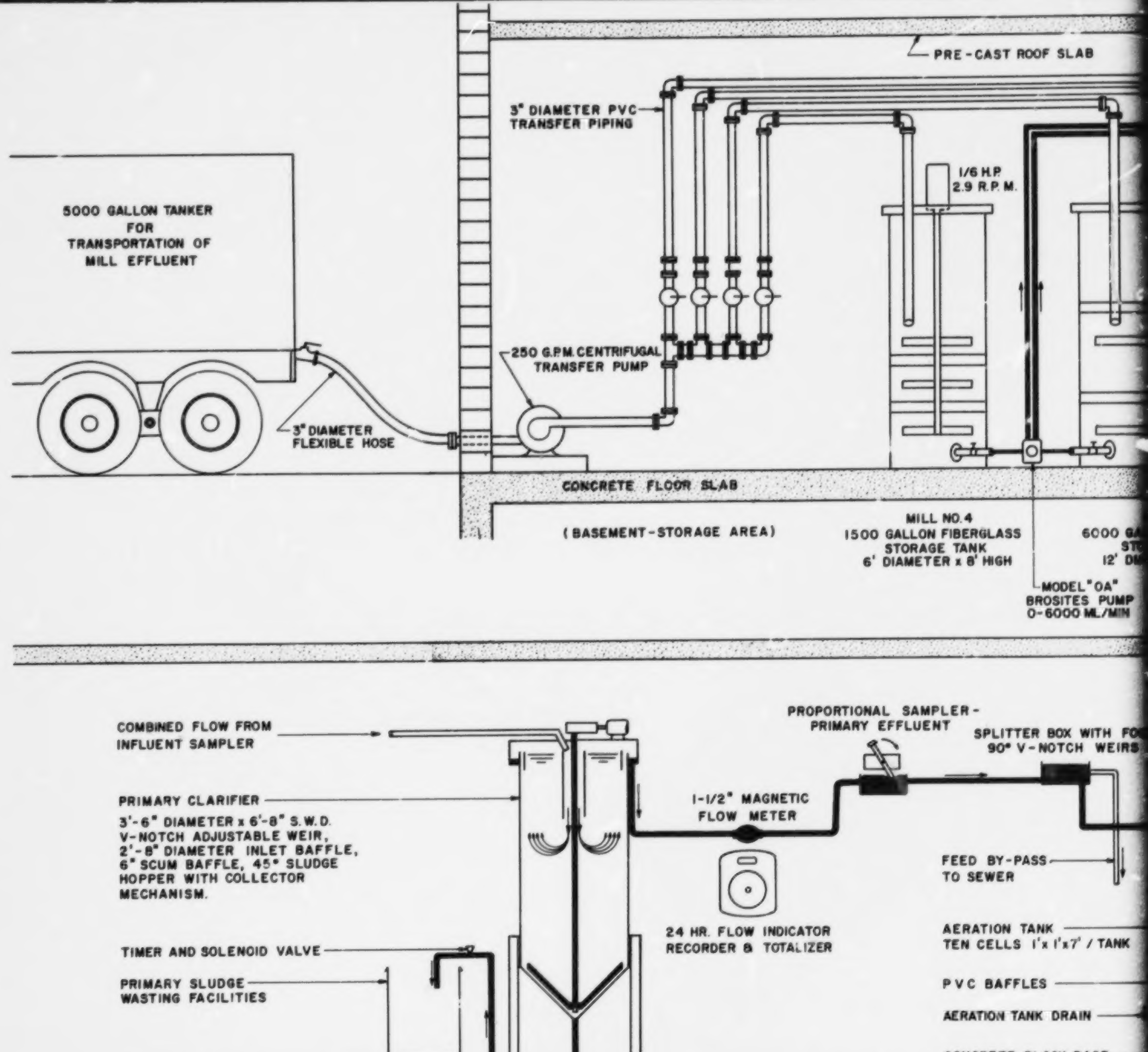

MUNICIPAL SEWAGE
MILL NO. 3
MILL NO. 2
MILL NO. 1
MILL NO. 4
PILOT PLANT REACTORS
SINK
DESK
DOWN
RAPID-MIX TANK
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
KRAUS
CONTACT STABILIZATION
AERATION TANKS
STEP AERATION
CONVENTIONAL
FINAL CLARIFIERS
WASTE SLUDGE FACILITIES
TO SEWER
SAMPLE REFRIGERATOR
POWER PANEL
MILL EFFLUENTS FROM TANK TRAILER
AIR COMPRESSORS
LEGEND
PROPORTIONAL SAMPLER UNIT
RETURN ACTIVATED SLUDGE PIPING
WASTE ACTIVATED SLUDGE PIPING
POSITIVE DISPLACEMENT PUMP
CELL FILLED WITH TAP WATER, (DEAD CELL)
DIGESTER SUPERNATANT FEED SYSTEM

GREEN BAY METROPOLITAN SEWERAGE DISTRICT
INDUSTRIAL-MUNICIPAL RESEARCH PROJECT

FLOOR PLAN - PILOT PLANT
ACTIVATED SLUDGE TREATMENT PROCESSES

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE 3/16" = 1'-0"

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX


PRE-CAST ROOF SLAB
3" DIAMETER PVC TRANSFER PIPING
5000 GALLON TANKER FOR TRANSPORTATION OF MILL EFFLUENT
1/6 H.P. 2.9 R.P.M.
250 G.P.M. CENTRIFUGAL TRANSFER PUMP
3" DIAMETER FLEXIBLE HOSE
CONCRETE FLOOR SLAB
(BASEMENT-STORAGE AREA)
MILL NO.4 1500 GALLON FIBERGLASS STORAGE TANK 6' DIAMETER x 8' HIGH
6000 GA
STO
12' DI
MODEL "OA" BROSITES PUMP 0-6000 ML/MIN
COMBINED FLOW FROM INFLUENT SAMPLER
PROPORTIONAL SAMPLER - PRIMARY EFFLUENT
SPLITTER BOX WITH FO
90° V-NOTCH WEIRS
PRIMARY CLARIFIER
3'-6" DIAMETER x 6'-8" S.W.D. V-NOTCH ADJUSTABLE WEIR, 2'-8" DIAMETER INLET BAFFLE, 6" SCUM BAFFLE, 45° SLUDGE HOPPER WITH COLLECTOR MECHANISM.
1-1/2" MAGNETIC FLOW METER
FEED BY-PASS TO SEWER
24 HR. FLOW INDICATOR RECORDER & TOTALIZER
AERATION TANK TEN CELLS 1'x 1'x 7' / TANK
TIMER AND SOLENOID VALVE
PRIMARY SLUDGE WASTING FACILITIES
PVC BAFFLES
AERATION TANK DRAIN
TO SEWER
CONCRETE BLOCK BASE

TOTAL PILOT PLANT FLOWS (G.P.M.)

	MIN.	AVE.	MAX.
INDUSTRY	1.85	1.85	1.85
METROPOLITAN	1.00	2.15	3.87
TOTALS	2.85	4.00	5.72

GREEN
INDU
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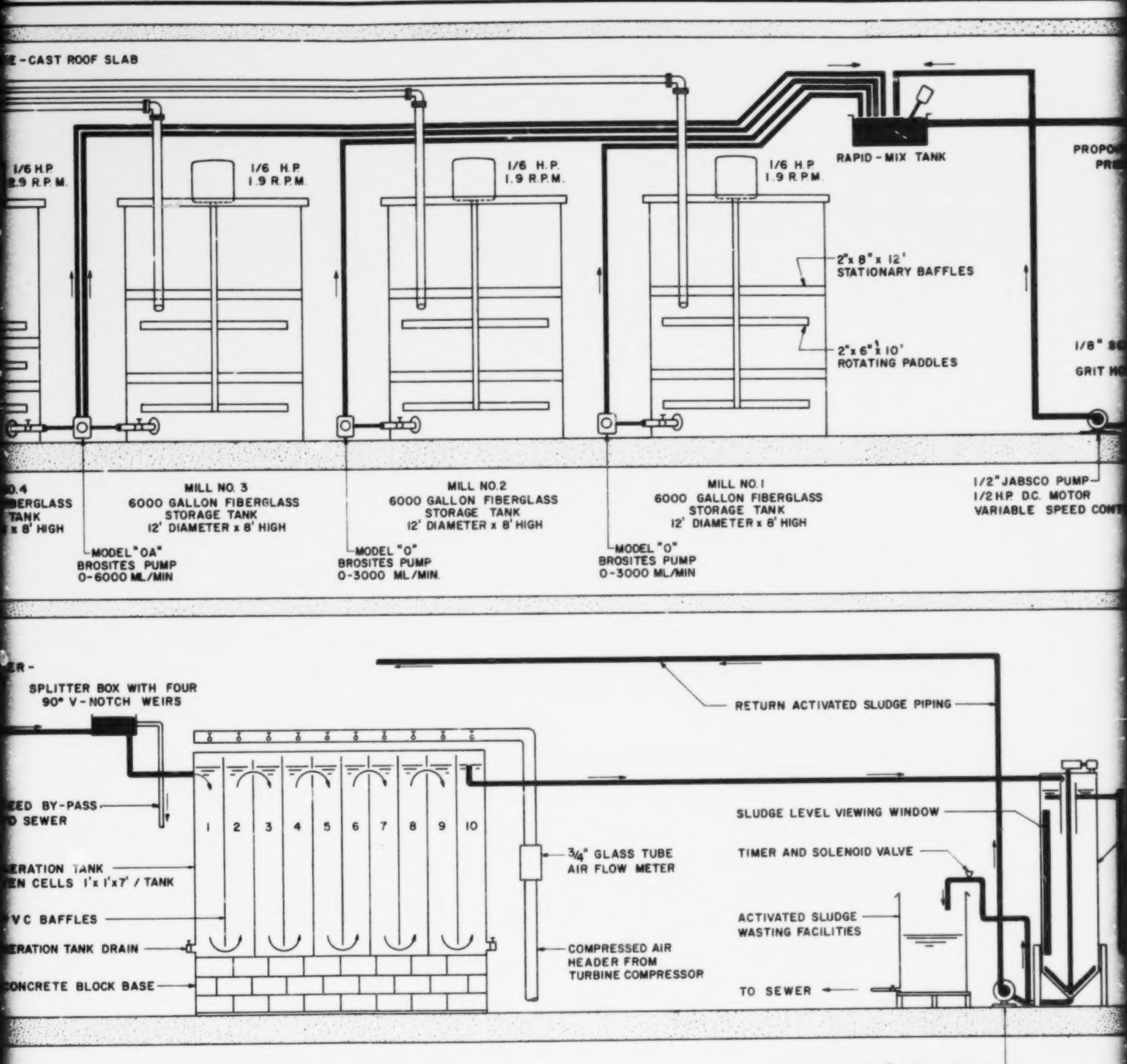
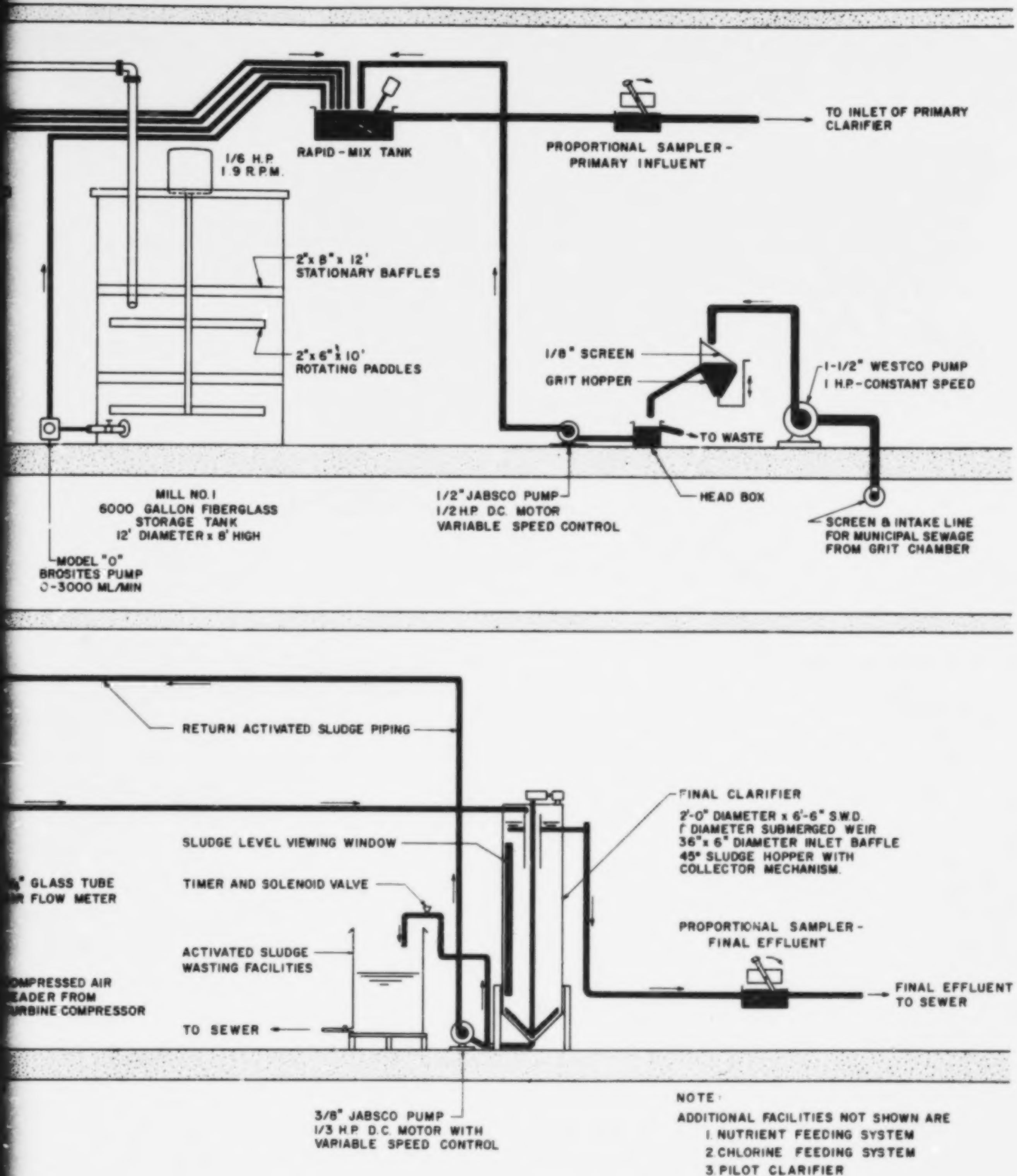

-CAST ROOF SLAB
1/6 H.P
2.9 R.P.M.
1/6 H.P.
1.9 R.P.M.
1/6 H.P.
1.9 R.P.M.
1/6 H.P
1.9 R.P.M.
RAPID - MIX TANK
PROPO
PR
2"x 8" x 12'
STATIONARY BAFFLES
2"x 6"½ x 10'
ROTATING PADDLES
1/8" SC
GRIT HO
O.4
BERGLASS
TANK
x 8' HIGH
MILL NO. 3
6000 GALLON FIBERGLASS
STORAGE TANK
12' DIAMETER x 8' HIGH
MILL NO. 2
6000 GALLON FIBERGLASS
STORAGE TANK
12' DIAMETER x 8' HIGH
MILL NO. 1
6000 GALLON FIBERGLASS
STORAGE TANK
12' DIAMETER x 8' HIGH
1/2" JABSCO PUMP
1/2 H.P. D.C. MOTOR
VARIABLE SPEED CON
MODEL "OA"
BROSITES PUMP
0-6000 ML/MIN
MODEL "O"
BROSITES PUMP
0-3000 ML/MIN.
MODEL "O"
BROSITES PUMP
0-3000 ML/MIN
ER-
SPLITTER BOX WITH FOUR
90° V-NOTCH WEIRS
RETURN ACTIVATED SLUDGE PIPING
EED BY-PASS
O SEWER
1
2
3
4
5
6
7
8
9
10
ERATION TANK
EN CELLS 1' x 1' x 7' / TANK
VC BAFFLES
ERATION TANK DRAIN
CONCRETE BLOCK BASE
3/4" GLASS TUBE
AIR FLOW METER
COMPRESSED AIR
HEADER FROM
TURBINE COMPRESSOR
SLUDGE LEVEL VIEWING WINDOW
TIMER AND SOLENOID VALVE
ACTIVATED SLUDGE
WASTING FACILITIES
TO SEWER
3/8" JABSCO PUMP
1/3 H.P. D.C. MOTOR WITH
VARIABLE SPEED CONTROL

GREEN BAY METROPOLITAN SEWERAGE DISTRICT
INDUSTRIAL - MUNICIPAL RESEARCH PROJECT
PILOT PLANT-SCHEMATIC FLOW DIAGRAM
ACTIVATED SLUDGE TREATMENT PROCESSES

DONOHUE & ASSOCIATES, INC. CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN

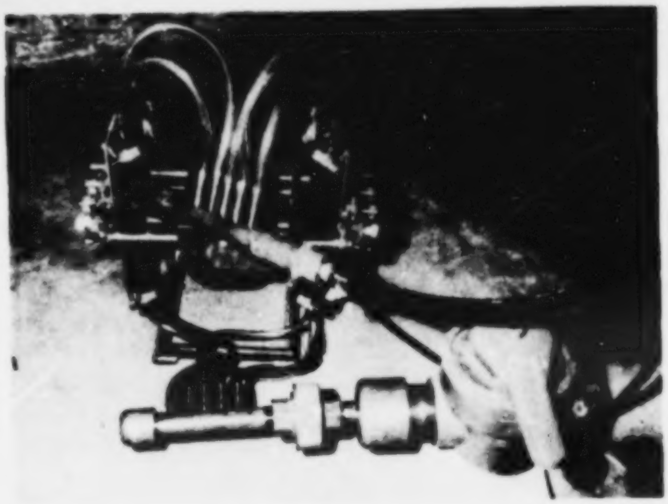

TO INLET OF PRIMARY CLARIFIER
RAPID-MIX TANK
PROPORTIONAL SAMPLER - PRIMARY INFLUENT
1/6 H.P. 1.9 R.P.M.
2"x 8" x 12' STATIONARY BAFFLES
2"x 6"½ x 10' ROTATING PADDLES
1/8" SCREEN
GRIT HOPPER
1-1/2" WESTCO PUMP
1 H.P.-CONSTANT SPEED
TO WASTE
MILL NO. 1
6000 GALLON FIBERGLASS STORAGE TANK
12' DIAMETER x 8' HIGH
1/2" JABSCO PUMP
1/2 H.P. D.C. MOTOR
VARIABLE SPEED CONTROL
HEAD BOX
SCREEN & INTAKE LINE FOR MUNICIPAL SEWAGE FROM GRIT CHAMBER
MODEL "O" BROSITES PUMP
0-3000 ML/MIN
RETURN ACTIVATED SLUDGE PIPING
FINAL CLARIFIER
2'-0" DIAMETER x 6'-6" S.W.D.
1' DIAMETER SUBMERGED WEIR
36"x 6" DIAMETER INLET BAFFLE
45° SLUDGE HOPPER WITH COLLECTOR MECHANISM.
SLUDGE LEVEL VIEWING WINDOW
½" GLASS TUBE
R FLOW METER
TIMER AND SOLENOID VALVE
ACTIVATED SLUDGE WASTING FACILITIES
PROPORTIONAL SAMPLER - FINAL EFFLUENT
OMPRESSED AIR
EADER FROM
RBINE COMPRESSOR
FINAL EFFLUENT TO SEWER
TO SEWER
3/8" JABSCO PUMP
1/3 H.P. D.C. MOTOR WITH VARIABLE SPEED CONTROL

NOTE:

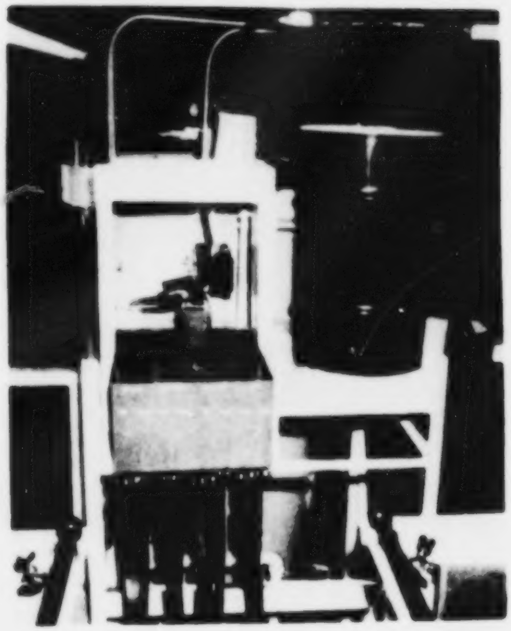
ADDITIONAL FACILITIES NOT SHOWN ARE
1. NUTRIENT FEEDING SYSTEM
2. CHLORINE FEEDING SYSTEM
3. PILOT CLARIFIER

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PROJECT 12130 EDX

FIGURE 4 PAGE 35

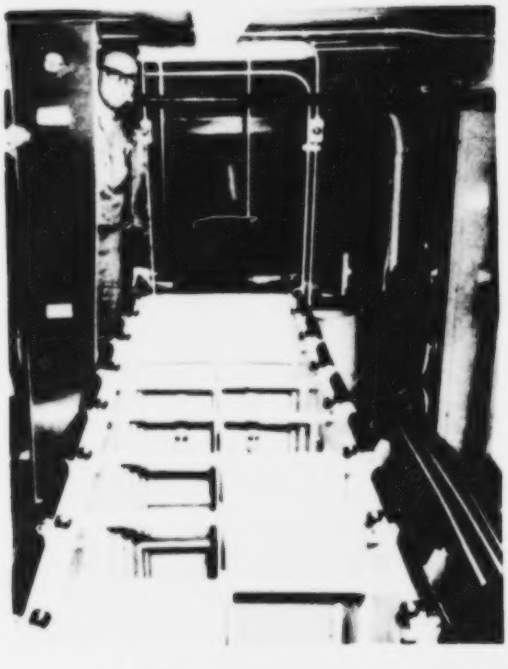


BROSITES PUMPS



RAPID-MIX TANK & SPLITTER BOX

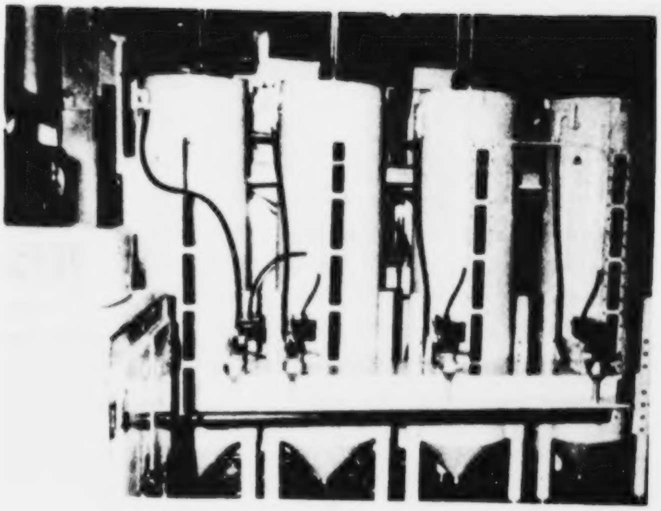
SPLITTER BOX



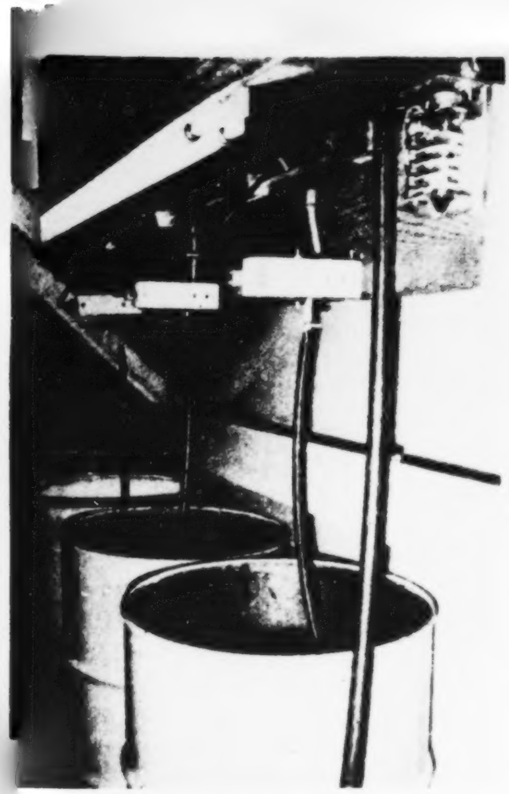
AERATION TANK & BAFFLES

PILOT PLANT EQUIPMENT PHOTOS

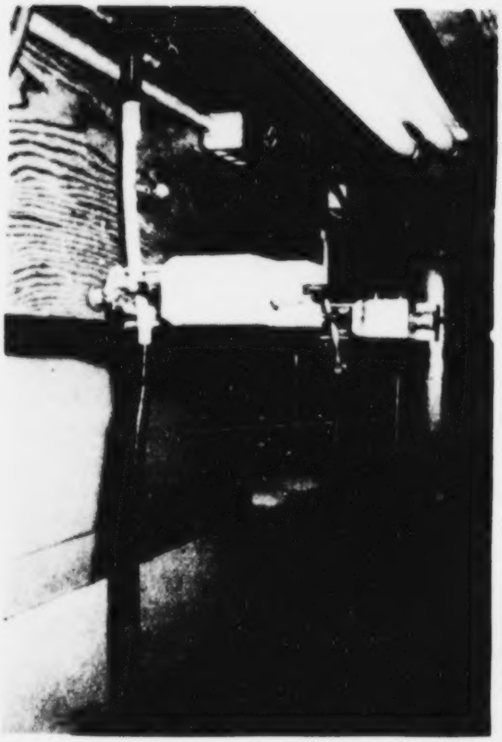
FIGURE 5 PAGE 37



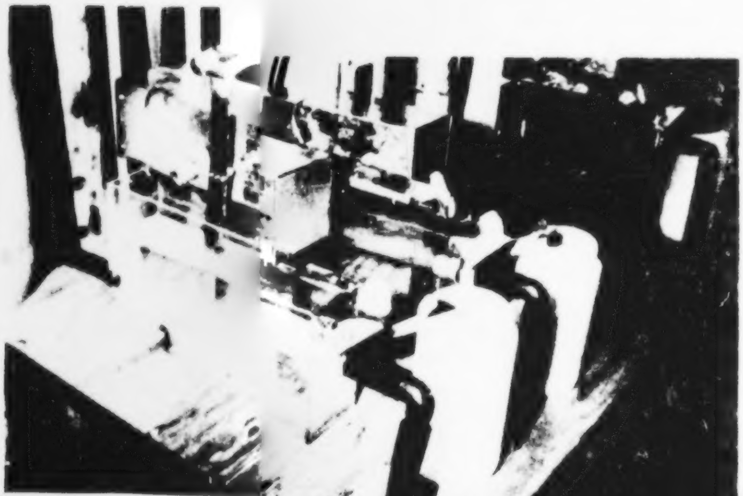
FINAL CLARIFIERS & FINAL EFF SAMPLERS



WAS VALVES & TIMER



WAS SOLENOID VALVE



FINAL EFFLUENT SAMPLERS

PILOT PLANT EQUIPMENT PHOTOS

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FIGURE 6

This pump performed quite well, maintaining consistent pumping rates as the concentration of RAS varied.

Flow Meter

A Foxboro 1-1/2 inch magnetic flow transmitter and accompaning indicator-recorder-totalizer were utilized to measure the total flow through the four plants. The instrument required calibration several times but basically worked quite well. It was also necessary to occasionally put a voltage of 110 volts across the meter probes which extend into the liquid flow to remove grease and other materials that had accumulated on the probes.

Aeration Tanks

There was considerable difficulty in solving the problem of sealing the individual baffles in the aeration tanks. Since the cells which were not in use were filled with tap water to equalize the hydraulic pressure on the division baffle, it was necessary to have a water-tight seal to prevent intermixing of tap water and mixed liquor. The solution was to use a 1/8 - inch thick, single-piece PVC baffle with a flexible PVC gasket sealed to the edge of the baffle. Stainless steel channels were mounted to the sides and bottoms of each aeration tank at one-foot intervals. The baffles were then placed into the channels forming a relatively water-tight seal.

Air Compressor

The primary air compressor was a Spencer Turbo Compressor; (170 scfm at 3500 rpm). The standby air compressor was a Yeomans positive displacement, multi-cellular, high speed rotary air compressor, (Model 45, 70 scfm at 1750 rpm). The compressed air passed through two Microclean (Model 1B2G) air line filters. During the research project the Yeomans unit was never utilized as the turbo compressor operated continuously with no problems.

Air Flow Meters, Valves and Diffusers

A Wallace and Tiernan glass tube Varea-Meter was installed on the air header to each aeration tank and needle valves were used for individual air control to each cell.

Filtros porous diffuser stones were obtained for diffusing air into the mixed liquor, and were sealed with an RTV silastic material into 10" x 10" square x 2" deep stainless steel pans leaving a 1" plenum chamber beneath the stone. However, shortly after plant startup the sealant proved unsatisfactory for this application. Many different adhesives were tried but none were successful in retaining a bond to the stainless steel. As an alternate solution, a pan was made from PVC material and a porous stone bonded to the pan with an epoxy adhesive.

Shortly after startup, foaming problems developed on the surface of the aeration tanks due to the very fine bubble diffusion. In order to minimize the foaming, all diffuser stones were removed and replaced with a hose extending to the bottom of each aeration cell which provided adequate coarse-bubble aeration.

Sampling System

Continuous composite samples, proportional to the total flow through the pilot plants, were taken of the primary influent, primary effluent, and four final effluents. Each sampler consisted of a rotating arm and cup mounted above a rectangular box inserted in the liquid flow line. Pictures of the samplers are shown in Figure 6. An electrical schematic diagram of the sampling system is shown in Figure 7.

Miscellaneous Feeding Systems

As it was difficult to maintain accurate low flows when utilizing a Brosites pump to feed dilute solutions of various liquids to the pilot plants, another feeding system was devised. The solution to be fed was continuously pumped through a sampling box. A continuously rotating cup dipped into the box and transferred a portion of the solution to a trough leading to the desired location.

Two other feeding systems used were:

1. An Essex Brass Corporation "Sight Feed Lubricator" was utilized to feed a defoaming agent dropwise into the front section of the primary effluent splitter box.
2. A 1000 ml glass intravenous solution bottle with associated fittings and feed controls was used temporarily as a nutrient-feeding system.

ELECTRICAL SCHEMATIC FOR PROPORTIONAL SAMPLERS

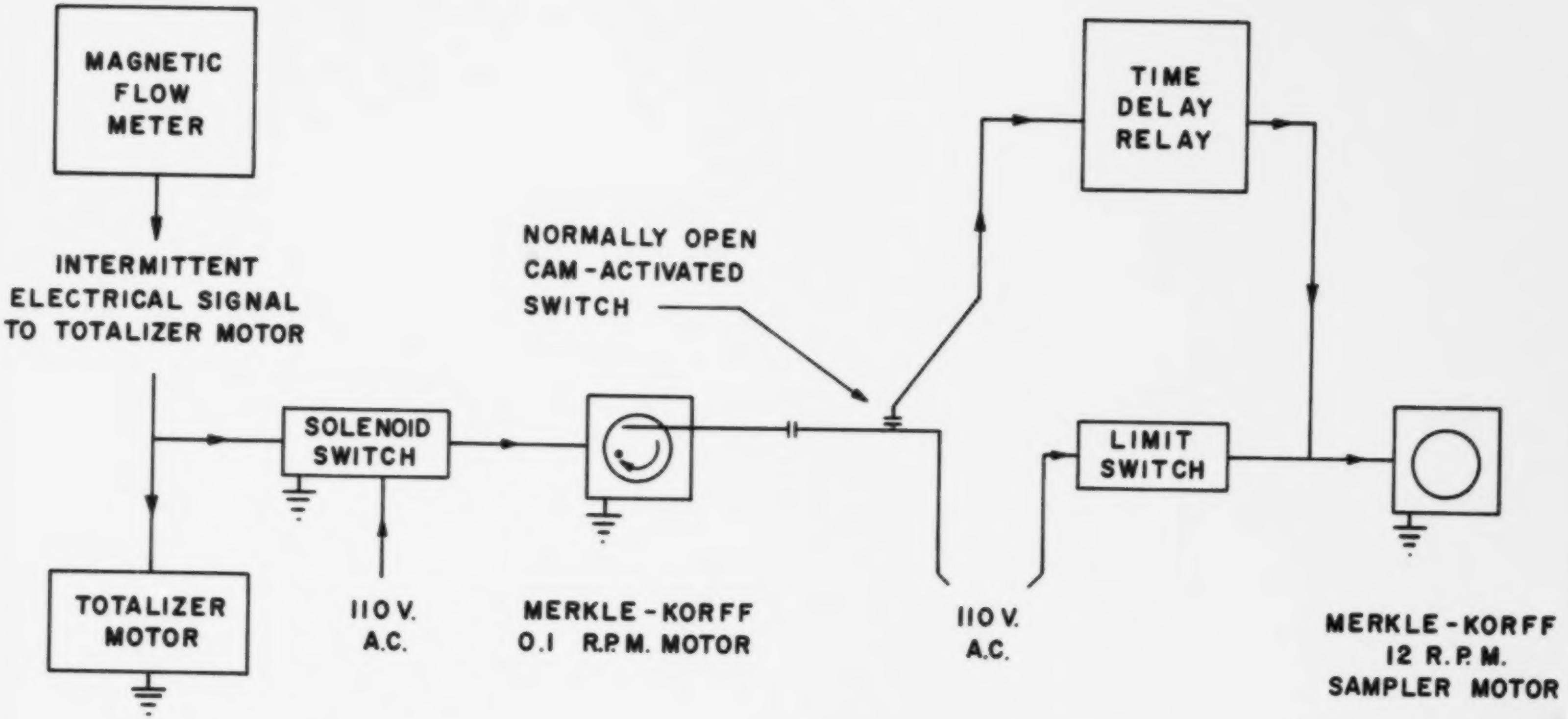
MAGNETIC FLOW METER
INTERMITTENT ELECTRICAL SIGNAL TO TOTALIZER MOTOR
TOTALIZER MOTOR
SOLENOID SWITCH
110 V. A.C.
MERKLE - KORFF 0.1 R.P.M. MOTOR
NORMALLY OPEN CAM - ACTIVATED SWITCH
TIME DELAY RELAY
110 V. A.C.
LIMIT SWITCH
MERKLE - KORFF 12 R.P.M. SAMPLER MOTOR

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FIGURE 7

Labor and Equipment Costs

The first items of pilot plant equipment were moved into the pilot plant room October 18; pilot plant startup with sewage was February 6, 1968. The pilot plant equipment costs, exclusive of labor, are summarized in Table 6. Approximately 2500 man-hours were required to construct the pilot plant facilities.

PILOT PLANT EQUIPMENT

Unit	Cost
Brosites, Jabsco and Viking pumps and related speed controllers and spare parts------------------------	$ 4,140
Mill effluent storage tanks and mixers----------------	$ 7,560
Preliminary treatment for grit removal---------------	$ 70
Primary clarifier------------------------------------	$ 1,060
Pilot clarifier--------------------------------------	$ 600
Aeration tanks and baffles--------------------------	$ 2,250
Diffused aeration system including porous stones, air flow meters, piping and valves----------------------	$ 1,080
Final clarifiers-------------------------------------	$ 3,740
Pilot digesters--------------------------------------	$ 200
Miscellaneous including sampling system, electrical switchgear, miscellaneous piping and maintenance items-	$ 2,300
TOTAL	$23,000

LABORATORY STAFF, EQUIPMENT, PROCEDURES AND DATA REDUCTION

Since the research project was short in duration, it was difficult to obtain qualified laboratory technicians. Therefore, individuals were trained as necessary to meet the qualifications and responsibilities of the particular position in question. The schematic of full-time and part-time personnel is illustrated in Table 7.

The laboratory was operated 6 days per week. Samples collected on Sunday were held over and analyzed on Monday. As estimate of the number of routine tests made during a typical month (May, 1969) is as follows:

BOD------------------ 440
COD------------------- 30
Nitrogen analyses------ 225
Phosphorus analyses----100
Solids Analyses--------1000

These estimates do not include the laboratory analyses associated with the special studies being conducted at the same time. The major laboratory equipment utilized for conducting the analyses is presented in Table 8.

The following tests were made routinely:

1. Biochemical oxygen demand - (BOD)
2. Chemical oxygen demand - (COD)
3. Ammonia, nitrite, nitrate nitrogen
4. Total organic nitrogen (biological cell nitrogen)
5. Ortho and total phosphorus
6. Solids analyses
    A. Total suspended and volatile suspended solids on influents and effluents - Gooch crucible method
    B. Total, total suspended and volatile suspended solids on sludges - Solids by difference method

Analyses for BOD, COD, and total organic nitrogen were conducted as specified in the 12th edition of "Standard Methods for the Examination of Water and Waste Water"(4). The procedure used for suspended solids analyses is as presented in Standard Methods with a Reeve Angel, grade 934AH, 2.4 cm, glass fiber filter used in lieu of an asbestos mat. The procedures for nitrogen and phosphorus are presented in Appendix B.

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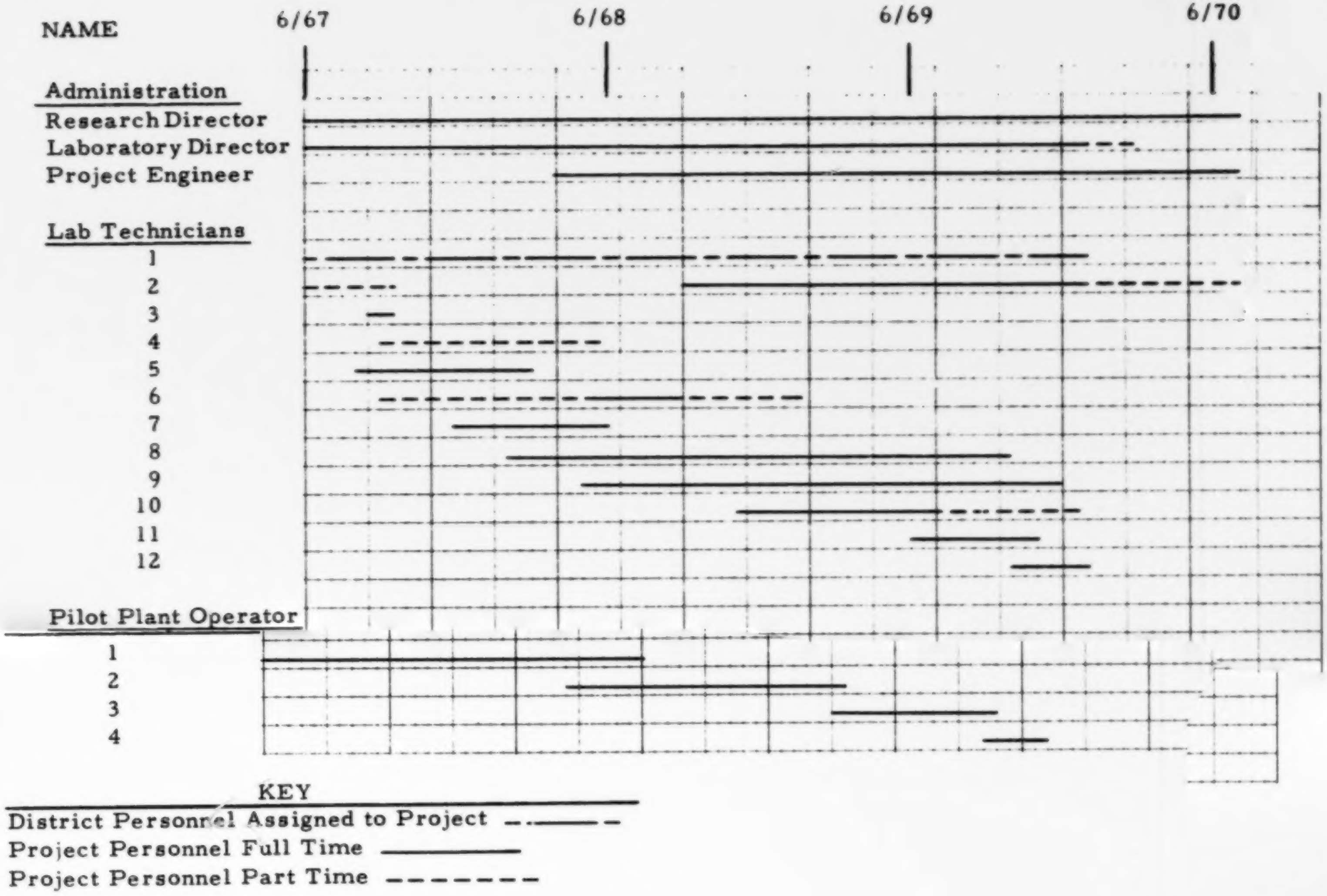
PROJECT PERSONNEL



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LABORATORY EQUIPMENT

Item	Model	Manufacturer
Calculator-Computer	Epic 3000	Monroe International, Inc., Orange, New Jersey
Balance-Christian Becker	Style AB-1, Serial #A13586 0-200 grams capacity	Christian Becker, Clifton, New Jersy
Balance-Sartorius	Model 2403, Serial #135222	Brinkman Instruments, Inc., Cantiague Road, Westburg, New York
Dissolved Oxygen Meter and Probe	Model 54	Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio
Dissolved Oxygen Recorder	Model 80	" " " " "
Oven	Model OV-484a, Serial #Q-A1753	Blue M Electric Co., Blue Island, Ill.
Furnace	Model E-555C-1, Serial #MF 564V	" " " " " " "
pH Recording Meter	Model 30 cordless	Analytical Measurements, Inc., 31 Willow St., Chatham, New Jersey 07928
pH Meter	Zeromatic II, Model 96A, Serial #009604-1000904	Beckman Instruments, Inc., Fullerton, California 92634
Specific Ion Meter	Model 404	Orion Research Inc., 11 Blackstone St., Cambridge, Mass. 02139
Sulfide Probe	Model 94-16	" " " " " "

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LABORATORY EQUIPMENT
(Continued)

Item	Model	Manufacturer
Process Carbonaceous Analyzer	No. 1389364, Range: 0-1000 mg/l Total Carbon; Leeds and Northrup type H Strip Chart; Model IR 315 Infrared Analyzer	Beckman Instruments, Inc., Process Instruments Division, Fullerton, Calif. 92634
Micro-Kjeldahl Distillation Apparatus	Keeny Still	Erway Glass Blowing, 686 Oak St., Oregon, Wisconsin 53575
Heating Mantle	5000 ml flask	Glas-Col. Apparatus Co., 711 Hulman St., Terre Haute, Indiana
Variable Autotransformer	2PF1010	Staco, Dayton, Ohio
Spectrophotometer	Spectronic 20, Serial No. 3493 4B	Bausch & Lomb, Inc., Rochester, New York
Phase Contrast Microscope	AO Series 10 Phasestar	Scientific Instrument Division; American Optical Corporation, P.O. Box 66499, Chicago, Illinois 60666

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The following special tests were conducted during the research project:

1. Color
2. Filterability index - (F.I.)
3. Oxygen uptake rate
4. Oxygen transfer
5. Specific filtration resistance - (SFR)
6. Sulfides
7. Total carbon - (TC)

Nitrogen Analyses

Prior to the research project the GBMSD laboratory routinely ran ammonia, nitrate and total organic nitrogen as presented in the 11th Edition of Standard Methods. These methods were satisfactory for the normal mixture of domestic and industrial wastes received at the treatment plant and for the research conducted jointly with Mill 2 between 1964 and 1966. However, upon starting the laboratory reactors in 1967,it was found that the nitrate procedure (phenoldisulfonic acid method) could not be used for the reactors containing combined Mill and Metro wastes.

The Standard Methods procedure for the nitrate determination requires that nitrites be converted to nitrates, and that a parallel test for nitrites be made to obtain, by difference, the true value of nitrates. Hydrogen peroxide and potassium permanganate were tried but neither was satisfactory for converting the nitrites to nitrates. The potassium permanganate was especially troublesome, causing a black precipitate in the sample which did not dissolve when the phenoldisulfonic acid and ammonium hydroxide were subsequently added. The nitrite-nitrate procedure satisfactorily measured these components in the samples obtained from the laboratory reactor receiving Metro sewage only. Therefore, the problem was apparently due to interferences present in the Mill effluents.

Project consultants and the Pulp Manufacturer's Research League were contacted for assistance in developing an alternate nitrate procedure. Each responded with a number of suggested methods to solve the problem but none of those proposed had ever been used to analyze this particular combination of wastes. Most of the recommended procedures also required some form of pretreatment to remove the color interferences. (The normal procedures for color removal listed in Standard Methods were not successful in pretreating this combination of wastes to remove the color.) Limited nitrite and nitrate data were subsequently obtained on the reactors by using a combination of methods, but the results were not consistent. Due to the lack of time to investigate the problem in depth, no nitrite or nitrate data were obtained for the pilot plants during the first year of operation.

In October, 1968 two additional procedures for measuring forms of nitrogen were discovered:

1. A similar FWQA research project at Erie, Penn. utilized an Orion Specific Ion-Nitrate Probe to measure nitrate. They did not attempt to measure nitrites.(5)

2. Studies at University of Wisconsin, Wausau, were being conducted in which nitrogen analyses were being run on highly colored liquids such as manure pile seepage. The equipment utilized was a Micro-Kjeldahl Distillation Apparatus.

Due to previous problems associated with specific ion probes regarding sulfide measurements, the decision was made to first investigate the procedures utilized at the University of Wisconsin, Wausau.

Samples of the most troublesome combinations of effluents were taken to Wausau in February, 1969 and analyzed under the direction of Dr. Crabtree(6). There were no analytical problems in determining the ammonia, nitrite and nitrate concentrations in each of the samples. The procedure of direct distillation with the Micro-Kjeldahl unit, presented in Appendix B, solved the problem of measuring nitrite and nitrate nitrogen in the combination of mill wastes and GBMSD sewage. All nitrogen analyses were performed during the second year of pilot plant operation.

Phosphorous Analyses

For this research project, the phosphorus in a given sample was assumed to be composed of orthophosphorus, condensed phosphorus and organic phosphorus; the sum of which was the total phosphorus. Ortho plus condensed phosphorus was the primary phosphorus test conducted by the GBMSD laboratory prior to the research project. The procedure utilized was adopted from the Association of American Soap and Glycerine Producers Committee report.(7) It is basically a modification of the solvent extraction procedure as presented in the Water Analysis section of Standard Methods. There was no procedure presented in Standard Methods for the analyses of phosphorus in sewage or industrial wastes at the time this research was conducted.

Ortho plus condensed phosphorus analyses were made on the laboratory reactors periodically. Upon startup of the pilot plants, the decision was made to determine ortho and total phosphorus separately to permit BOD:N:P ratios to be calculated in the raw and nutrient-supplemented primary effluent.

This procedure is a slight modification of that for ortho plus condensed phosphorous; potassium persulfate is added in the digestion step to insure complete conversion of total phosphorus to ortho phosphorus(8) This procedure is presented in Appendix B.

Solids by Difference

When making solids analyses on samples with a high solids concentration, (mixed liquor, return and waste activated sludges) it was necessary to utilize a procedure which was accurate and yet rapid. The procedure utilized was developed by Drs. Polkowski and Boyle during 1964-66(2, 3).

Color

Dr. Wiersma(9) provided assistance in developing a suitable procedure for color analyses. Samples of the final effluents were analyzed on a spectrophotometer at wave lengths between 375 and 610 millimicrons. A plot of absorbance versus wave length showed a decreasing absorbance with increasing wave length. Therefore, during the first year, the absorbance and transmittance at 375, 420, 525 and 610 millimicrons were recorded. During the second year the 375 millimicron wave length was selected as the standard upon which all color measurements were made.

A platinum cobalt standard, which had the equivalent of 500 color units, was used to prepare a curve of percent transmittance versus color units at 375 millimicrons. With this curve the color, in standard color units, could be obtained for the given sample. This procedure is presented in Appendix B.

Filterability Index Test

This test, which was developed to measure the relative ability to filter the four final effluents, was utilized as a criterion in selecting the most desirable process.

The procedure used was adapted from the work of Hahn(10). The equipment utilized during the project required that two persons conduct the analyses to obtain the best accuracy; the interpretation of the results was quite subjective and the information gained was of relative value only. This test was utilized only during the first year of research.

Oxygen Uptake and Transfer

The procedures for oxygen uptake and oxygen transfer are presented in Appendix B. Small laboratory reactors, containing mixed liquor from the respective pilot plants, were utilized to obtain oxygen uptake and transfer values between February, 1968 and August, 1969. During the fall of 1969, when the contact stabilization process was being studied intensively, the oxygen uptake analyses were conducted in the aeration cells of the particular pilot plant being analyzed.

Specific Filtration Resistance

This procedure was adapted from the method presented by Coackley(11).

Sulfides

Due to the presence of filamentous sulfur bacteria in the pilot plants during March, 1968, it became necessary to measure the quantity of sulfides in the various streams associated with the pilot plants. A specific ion-sulfide probe manufactured by Orion Research, Inc. was used with a Beckman Zeromatic pH meter and single-junction reference electrode. Millivolt and pH readings were obtained to determine the total sulfide content.

Since a single-junction rather than a double-junction reference probe was erroneously used between March, 1968 and February, 1969, the values obtained during the first year are primarily useful as relative values of the sulfide concentration. However, this information led to the decision to begin chlorinating the return activated sludge streams of the conventional and step aeration units in January, 1969.

An Orion Model 404 Specific Ion Meter was used for pH and sulfide measurements during the second year; a double-junction reference electrode was also obtained for making correct sulfide measurements. The sulfide values obtained during the second year are considered to be as accurate as the limits of the equipment and procedure would permit.

Based on information provided by Orion Scientific, Inc., measured total sulfide concentration values less than 10^{-7} moles/liter (.003 mg/l) would be highly questionable. In regard to the minimum limits of detection of total sulfides in an unknown, Dr. Lee(12) stated that the minimum concentration accurately measurable would be about 0.01 mg/l as total sulfides when measuring pH to the nearest 0.1. He further stated that values less than 10^{-4} mg/l total sulfides should be reported as a trace, negligible, or value in question.

Although Orion Research, Inc. has developed procedures for a direct meter readout of total sulfide concentration called the "Known Addition Method" and the "Known Subtraction Method", it was the conclusion of the project laboratory staff and Dr. Wiersma, who assisted in developing the procedure, that the procedure utilizing millivolt and pH measurements is much simpler and much less cumbersome than any other procedure developed to date. This is primarily because the "Known Addition" and "Known Subtraction Methods" require a multiplicity of standards when the range of the total sulfide concentration in the unknown is not known and the fact that these standards are not stable for long periods of time.

In summary, the measurements of sulfides was a very difficult procedure to accurately develop for the research project. However, once the proper equipment had been obtained, and the procedure had been developed satisfactorily, the measurement of the sulfides became a routine test. The procedure for total sulfide concentration measurements is in Appendix B.

Total Carbon

A Beckman Process Carbonaceous Analyzer was used for total carbon analyses. The analyzer had a range of 0 to 1000 mg/l total carbon, and utilized a Leads and Northrup type H strip chart and a Model IR315 infrared analyzer. A manual injection procedure was utilized.

The following samples were analyzed periodically for total carbon (TC) during 1968 and 1969:

1. Four Mill wastes.
2. Metro sewage.
3. Combined primary clarifier influent.
4. Primary clarifier effluent.

Total carbon analyses were made on final effluents during the first year. The BOD/TC ratios obtained were so variable that no correlation was apparent. Therefore, no final effluents were analyzed for total carbon during the second year.

During August, 1968, preliminary studies were conducted to remove inorganic carbon by acidifying the samples to a low pH and then heating the samples to drive off CO_2. The procedure was quite time-consuming and did not appreciably change the total carbon content of the sample. Blending the individual samples of Mill wastes, Metro sewage, combined primary influent, and primary effluent in a Waring Blender with a special high-shearing head was also investigated; there were no significant differences in the total carbon values obtained for the blended and unblended samples. Therefore, the decision was made to analyze the samples with no pretreatment, acknowledging the fact that there may be some inorganic carbon present which is measured with the organic carbon in the sample. Therefore, all values presented in this report are as total carbon, not total organic carbon.

The results of the correlation studies between BOD, COD, total carbon, and total suspended solids are presented in the section entitled Total Carbon Correlations.

Laboratory Data Reduction

As the laboratory analyses were conducted, the results were entered on work sheets. Sample computer printout laboratory data sheets are presented in Appendix B.

Selected parameters were plotted on graph paper to aid in monitoring the daily operation of the pilot plants. The parameters plotted during the first year were:

1. Primary effluent: pH, BOD, COD, BOD:N:P
2. Conventional process:
   - Aeration tank:
     - MLVSS - Cell 10
     - RAS - TSS
     - Settled Sludge Volume - SVI Test
     - SVI
     - F/M ratios - BOD/MLVSS, COD/MLVSS
   - Final effluent:
     - BOD, mg/l - filtered and unfiltered
     - BOD, % reduction - filtered and unfiltered
     - TSS, mg/l
   - Final clarifier sludge level

3. Step aeration process:
   The values graphed for the step aeration process were identical to the conventional process; in addition the MLVSS for Cells 4, 6 and 8 were also plotted.

4. Contact stabilization
   The information plotted was the same as for the conventional process; in addition the MLVSS of the last cell of the reaeration section was also plotted.

5. Kraus process:
   The items plotted were the same as for the contact stabilization process.

In addition to the graphs of selected parameters, a summary of the daily operational logs and the periodic microbiological examinations was also chronologically recorded on graphs for each process.

During the second year, the same parameters were plotted for the contact stabilization and Kraus processes with the following exceptions:

1. The F/M ratio, COD/MLVSS, was not plotted for either process.
2. The final effluent-filtered BOD was not plotted for either process.

An example of the graphs is presented in Appendix B.

In the early stages of the research project, the possibility of computerizing the data obtained from the laboratory analyses to perform various correlation studies was evaluated and the decision was made to proceed with this method of data reduction. An IBM 1401 computer was used with the Auto-Coder computer language. This language was selected in lieu of Fortran because of the availability of programmers locally. A program was developed which printed out the laboratory data in a facsimile of the laboratory data sheets. The format of the laboratory data sheets was changed for the second year, necessitating a considerable revision of the Auto-Coder program.

One benefit of computerizing the data was the ability to cross check the calculations made by laboratory personnel and the computer. Due to the large quantity of laboratory data generated, the possibility of errors was great. By cross checking the computer data with the laboratory data sheets, errors were discovered both on the computer printout and on the laboratory data sheets thus permitting the appropriate corrections to be made.

Having laboratory data neatly typed on a computer printout sheet is ideal for clear photo-reduction and incorporation into reports as desired. However, in retrospect, computerization of the data was not justified in this project due the fact that: (1) there were a considerable number of variations in the laboratory forms between the first and second year, (2) there were many variations in plant operation which required changing the volumes of the aeration sections and the flow rates thus necessitating a change of constants involved in the computer programs, and (3) the Auto-Coder language was not easily adaptable to make correlations of the laboratory data obtained. It is recommended that computerization of laboratory data only be considered under the conditions were (1) a scientific language is used, (2) a minimum of individual processes generate the data and (3) these processes be limited to a minimum of operating changes during the period of study.

PILOT PLANT OPERATION

Mill Effluent Transportation and Storage

Between June and August, 1967, laboratory studies were conducted to determine if there were any significant changes in the initial BOD and pH values of the Mill wastes due to long-term storage. It was concluded that changes in these parameters due to storage were not significant when compared to the expected variations in waste characteristics over the period of the project. Mill wastes were hauled to the pilot plant site in a 5,000 gallon tank trailer and pumped into storage tanks for use in the pilot plants as desired.

Mill Effluent Contracts

As the GBMSD was the sole grant applicant, it was necessary to develop contracts between the Mill participants and the GBMSD to provide for the construction of necessary pumping and storage facilities at the Mill site and disposal of this equipment at the conclusion of the project. The procedure which was developed is as follows:

1. Each of the Mills installed the necessary equipment to load the tank trailer with characteristic Mill wastes.
2. The salvageable value of the equipment was subtracted from the total cost of the installation and the balance constituted a payment to the Mill by the research project.

Arrangements were made to lease a 5,000 gallon stainless steel tank trailer at a flat rate of $50.00 per week. The cost for a tractor and driver was $10.00 per hour during the first year and $10.50 per hour during the second year.

A summary of the total volumes and cost of delivery of the respective mill wastes is presented below.

2/16/68 - 12/12/69	Volume, Gallons	Cost	Cost/1000 Gallons
Mill 1	291,015	$1145.17	$ 3.94
Mill 2	345,200	1691.69	4.90
Mill 3	561,650	2583.89	4.60
Mill 4	122,760	1646.03	13.41**
Total	1,320,625	$7066.78	$ 5.35

**Note: The average tank trailer load for Mill 4 was approximately 1000 gallons per trip resulting in the high unit cost shown.

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Pilot Plant Operation

The pilot plants were operated continuously 24 hours per day, 7 days per week. The pilot plant operator was on duty 5 1/2 days per week. In the absence of the pilot plant operator, the GBMSD treatment plant operators checked the pilot plants at least once hourly, taking required samples, reading final clarifier sludge levels, and making routine checks for mechanical problems. If a mechanical problem was discovered which could not be quickly repaired, project personnel were called in.

In order to control the pilot plant operation, it was necessary to take many samples of the streams associated with each pilot plant. The routine sampling program is presented in Table 9.

In order to properly control the pilot plant operation, equations were developed to mathematically estimate the required flow rates for feed bypass, return activated sludge (RAS) and waste activated sludge (WAS).

During the periods of operation in which the mixed liquor had poor settling characteristics, it was necessary to bypass a portion of the primary effluent in order to maintain the F/M (food/microorganism) ratio in the desired range. As the plant improved, the quantity of bypass would be gradually reduced to zero. The COD/BOD ratio was used so that daily changes to the bypass rate could be made as necessary. The primary objective of controlling the RAS and WAS flows was to maintain the proper quantity of mixed liquor volatile suspended solids under aeration. In doing so, the F/M ratio was maintained at the selected level.

The daily procedure was to mathematically calculate the theoretical values for RAS and WAS and then, based upon previous operating history use these values to adjust the flows accordingly. For example, if the particular plant had been operating at a very steady condition over several days, the calculated value would normally be used as the setting for the next day. However, if the operation had been fluctuating greatly and there was a low concentration of solids in the return activated sludge thus resulting in a very high calculation for the RAS flow setting for the next day, the RAS flow actually set would be less than that calculated. This procedure was also applied to the waste activated sludge flow. For example, if a sludge blanket was building up in the final clarifier, the amount of activated sludge wasted would be greater than that calculated to maintain the blanket at the desired level.

Mill wastes were pumped from storage tanks on a constant flow basis. Pumping rates for Metro sewage were adjusted manually to approximate

PILOT PLANT SAMPLING PROGRAM

Source	Procedure
PI, PE, 4 FE's*	Automatic sampling, 24 hours per day, 7 days per week, proportional to total flow to four pilot plants.
Nutrients (N & P)	Weighted grab samples of freshly-filled nutrient-feed barrel, composited and analyzed at selected intervals or daily as operation dictated.
Digester Supernatant	Grab sample of freshly-filled supernatant-feed barrel; normally a daily operation.
Chlorine	Strength of concentrated chlorine solution added to chlorine feed barrel determined; concentration of chlorine fed to pilot plants calculated using known dilution factor.
Aeration Tank Mixed Liquor	Daily grab sample of specified cells of aeration tank.
Return Activated Sludge (RAS)	2/6/68 to 8/29/68 - Representative grab sample of total WAS collected previous 24 hours. If no wasting occurred, then a grab sample of RAS was taken at the same time as the mixed liquor grab sample.
	8/30/68 - 12/15/69 - Composite grab samples, on odd hours, 24 hours per day, 6 days per week.
Waste Activated Sludge (WAS)	Solids concentration assumed to be same as RAS, therefore no separate samples of WAS taken.

* PI - Primary influent
PE - Primary effluent
FE - Final effluent

Table 9

flow variations through the GBMSD plant. Adjustments were made hourly or when significant changes in flow occurred.

The frequency of measuring pilot plant operating parameters is presented in Table 10.

PILOT PLANT MEASUREMENTS

Source	Flow Rate	Volume	Miscellaneous
Mill Storage Tank Pumps	1/week		
Metro Sewage Pump	1/month		
Magnetic Flow Meter		7 days/week	
Bypass	6 days/week		
RAS	" " "		
WAS	" " "	7 days/week	
Nutrients	" " "		
Digester Supernatant	" " "		
Chlorine	" " "		
Dissolved Oxygen:			
All Cells			6 days/week
Temperature, Cell 10			" " "
Final Clarifier Sludge Levels			Even hours - 7 days/week
Mixed Liquor SVI			6 days/week

PRIMARY CLARIFICATION

During the pilot plant design, the provision of primary clarification was questioned due to the fact that the industrial wastes which were approximately 50% of the hydraulic flow, had relatively few settleable solids. The decision was made that primary clarification would be provided to properly evaluate it's desirability in a full-scale plant.

A single primary clarifier was installed to serve the four secondary treatment units. The details of the primary clarifier construction are shown on the as-built drawing in Appendix A. The unit was designed to provide a two-hour detention time at four gallons per minute.

Five special studies on primary clarification were made:

1. Preliminary evaluation of primary clarifier performance -- July 25, 1968.
2. Imhoff cone and gravity settling column tests -- November 11, 1968 - January 16, 1969.
3. Imhoff cone and gravity settling column tests -- February 26-27, 1969.
4. Pilot clarifier studies -- May 1 - July 31, 1969.
5. Pilot clarifier studies -- September 1 - October 19, 1969.

As discussed previously, joint treatment options required study of the following combinations:

1. Each Mill alone.
2. Metro alone - average and simulated storm flow.
3. Mills 1, 2 and 4.
4. Mills 1, 2, 4 and Metro.
5. Mill 3 and Metro.
6. All Mills and Metro.
7. All Mills and Metro plus WAS return to the primary clarifier.

Preliminary Evaluation of Primary Clarifier Performance - 7/25/68

Primary clarifier BOD and total suspended solids (TSS) removal data for the period between March 1 and June 30, 1968, averaged 4.2% and 33% respectively when treating the combination of all Mills plus Metro wastes. On the basis of BOD removal alone, primary clarification could not be justified. Also, a total suspended solids removal of 33% is considerably less than average values of 50-60% normally obtained in primary treatment units treating domestic wastes. However, proper evaluation of primary clarification must also consider these additional factors:

1. Efficiency of primary clarification on various combinations of the five individual wastes.
2. Increase in sulfide concentration of the sewage as it passes through a primary clarifier.
3. Preaeration of the sewage prior to entering the aeration tank.
4. Reduction in waste activated sludge produced due to removing solids in primary clarification.
5. Evaluation of primary and secondary sludge characteristics.
6. Desirability of returning waste activated sludge to the primary clarification units.

Until these factors could be investigated, it was decided to continue primary clarification of all influents to the pilot plants.

Imhoff Cone and Gravity Settling Column Tests, 11/1/68 - 1/16/69

A series of Imhoff cone settling analyses was made for four combinations of Mill and Metro wastes on November 11, 1968. The combinations analyzed, the testing procedure, and the laboratory data for the initial composite samples are shown in Table 11 and 12. Samples of supernatant were taken after 30 minutes of settling, and after pH adjustment and 30 minutes of settling. It was assumed that the mill waste flows were fairly uniform over a 24-hour period as opposed to diurnal variations of Metro sewage flow. However, a single grab sample of Metro sewage was used in the studies, thus injecting a degree of uncertainty into the answers obtained.

An Imhoff cone study was made on the five individual wastes on January 13, 1969. These data are presented in Table 13. Gravity settling column tests were run on the five individual wastes on January 15-16 utilizing a 3 1/2 inch I.D. plastic settling column with a 12-foot sidewater depth. (See the section entitled "Final Clarification-Laboratory Procedure - Phase II in Appendix B).

The Mill samples used for the tests between January 13-16 were obtained from storage tanks which had been filled on the 6th and the 10th of January, (see notes on Table 13). Some changes in waste characteristics may have occurred during the storage period. The Metro sewage grab sample for the gravity settling column test was obtained from the hose which discharged to the rapid-mix unit in the pilot plant.

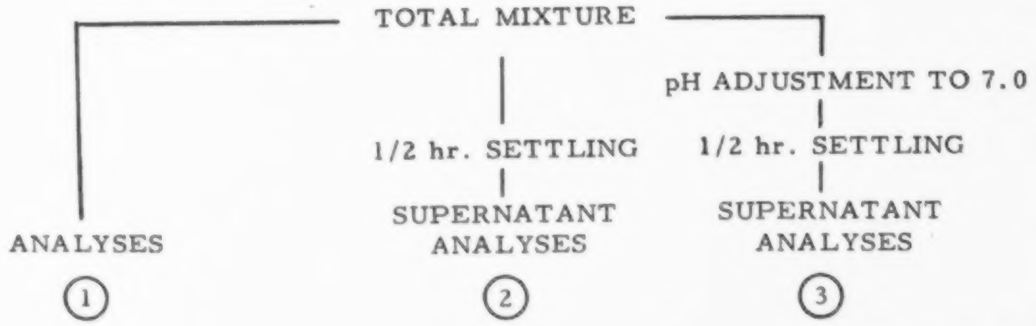
The data obtained from the gravity settling column tests were very disappointing and of little value. It was not possible to draw percent removal curves through the data as is typically done in data analysis.

PRIMARY CLARIFICATION INVESTIGATION
Imhoff Cone Analyses
Mill and Metro Combinations
November 11, 1968

SAMPLE COMPOSITION

A.	Mill 1	(4 MGD)
B.	Mill 2	(5 MGD)
C.	Mill 3	(7 MGD)
D.	Mill 4	(2.25 MGD)
E.	Metro	(20 MGD)
F.	Mill 1	3.57 liters
	Mill 2	4.43 liters
	Mill 4	2.00 liters
G.	Mill 1	1.29 liters
	Mill 2	1.60 liters
	Mill 4	0.72 liters
	Metro	6.39 liters
H.	Mill 1	1.05 liters
	Mill 2	1.31 liters
	Mill 3	1.83 liters
	Mill 4	0.59 liters
	Metro	5.22 liters
I.	Mill 3	2.59 liters
	Metro	7.41 liters

TESTING PROCEDURE


TOTAL MIXTURE
pH ADJUSTMENT TO 7.0
1/2 hr. SETTLING
1/2 hr. SETTLING
ANALYSES
SUPERNATANT ANALYSES
SUPERNATANT ANALYSES
①
②
③

PRIMARY CLARIFICATION INVESTIGATION

Imhoff Cone Analyses
Mill and Metro Combinations
November 11, 1968

Analyses, mg/l \ Samples	A	B	C	D	E
	1a	1	1	1	1
BOD - unfiltered	1350	968	563	1155	292
Total Suspended Solids	264	344	228	324	344
NH_3 - Nitrogen		213			

Analyses, mg/l \ Samples	F			G			H			I		
	1	2	3	1	2	3	1	2	3	1	2	3
BOD-Unfiltered	1275	1122	1114	719	629	623	725	640	640	507	422	459
BOD-Filtered	1105	887	1173	591	459	507	514	519	519	309	306	310
Total Solids	2876	2784	2916	1768	1648	1716	1760	1660	1680	1732	1604	1560
Total Volatile Solids	1924	2036	1420	1048	960	828	948	884	872	532	444	428
Total Suspended Solids	168	64	72	264	88	100	204	92	128	296	160	168
Vol. Suspended Solids	120	60	88	240	116	96	200	88	112	280	156	148
NH_3 - Nitrogen as N	86.8	86.2	87.9	47.0	56.6	48.2	39.0	33.4	39.5	17.8	17.0	8.0
Ortho-Phosphorus as P	0	0	0	3.5	3.2	3.1	3.0	3.3	2.7	5.1	4.7	4.4
Total-Phosphorus as P	0.4	0.3	0.3	7.5	6.9	6.8	10.6	5.8	5.6	9.5	9.2	8.5
Volatile Acids as Acetic	555	593	574	278	259	257	288	281	278	155	145	174
pH	5.25	5.3	6.8	6.7	6.6	6.8	6.7	6.7	6.9	7.2	6.9	6.9
Settled Sludge Vol. mls.		7	6.0		13	14		10	10		10	10

a. 1 - Total mixture
2 - Supernatant after 1/2 hour quiescent settling
3 - Supernatant after pH adjustment and 1/2 hour quiescent settling
b. Data reported under A, B, C and D are based on grab samples from freshly-filled storage tanks, 11/8/68.
c. Data reported under E are based on a 24-hour influent composite sample for 11/11/68.
d. Data reported under F, G, H and I are based upon mixtures composited from grab samples from the mill effluent storage tanks and Metro influent on 11/11/68.

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PRIMARY CLARIFICATION INVESTIGATION
Imhoff Cone Studies
Individual Mill and Metro Wastes
January 13, 1969

Samples / Analyses, mg/l	A - Mill 1			B - Mill 2			C - Mill 3		
	1	2	3	1	2	3	1	2	3
BOD-Unfiltered	1564	1428	1428	357	306	323	629	612	655
BOD-Filtered	1530	1428	1411	357	306	315	612	553	476
Total Solids	3548	3348	3976	1464	1348	1220	1920	1840	1912
Total Volatile Solids	2508	2332	1568	976	784	716	720	708	600
Total Suspended Solids	172	128	148	204	100	132	284	256	268
Vol. Suspended Solids	172	104	132	200	100	120	176	168	164
NH_3-Nitrogen as N	0	0	0	52.4	50.4	50.4	0	0	0
Ortho-Phosphorus as P	0.2	0.2	0.25	0.01	0	0	0.1	0.1	0.1
Total-Phosphorus as P	0.9	0.61	0.82	0.26	*	0.22	0.94	0.8	0.83
Volatile Acids as Acetic	559	669	565	171	174	169	243	274	245
pH	3.3	3.3	7.0	6.5	6.5	7.0	5.9	5.9	6.7
Settled Sludge Vol. mls.		7	5	18	18	18		1.7	.6

Samples / Analyses, mg/l	D - Mill 4			E - Metro		
	1	2	3	1	2	3
BOD–Unfiltered	1326	1275	1292	209	114	127
BOD-Filtered	1292	1207	1173	105	105	95
Total Solids	3972	3876	3992	988	868	440
Tot. Vol. Solids	1432	1336	1196	340	236	108
Total Sus. Solids	280	266	246	168	92	68
Vol. Sus. Solids	273	233	220	156	76	68
NH_3-Nitrogen	0	0	0	13.1	11.6	13.4
Ortho Phosphorus	0.03	0.01	0	2.7	2.2	2.3
Total Phosphorus	0.73	0.61	0.82	4.04	4.5	4.26
Volatile Acids as Acetic	771	812	757	40	45	38
pH	6.0	6.0	7.0	7.5	7.2	7.0
Settled Sludge Vol. mls.		4	3		24	19

Note:

a. 1 - Total Mixture
   2 - Supernatant after 1/2 hour quiescent settling.
   3 - Supernatant after pH adjustment and 1/2 hour quiescent settling.

b. Samples A and B are grab samples from storage tanks filled 1/6/69.

c. Samples C and D are grab samples from storage tanks filled 1/10/69.

d. Sample E is a 24-hour composite sample obtained 1/13/69.

* Analyses inconclusive

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Apparently, a majority of the particulate material in the Mill wastes is colloidal in nature and would not be removed by clarification. This is further indicated by the Imhoff cone studies conducted on January 13, in which the quantity of settled sludge is quite small for three of the four Mill wastes.

Imhoff Cone and Gravity Settling Column Tests, 2/26-27/69

As the Imhoff cone studies performed November 11, 1968 utilized grab samples of Metro sewage rather than composite samples over a period of 24 hours, a series of tests on composite samples was conducted a second time between 0800, February 26, and 0800 February 27, 1969. The sample compositions and relative volumes are presented in Table 14.

Two hour composite samples were obtained by taking Metro grab samples every 15 minutes proportional to the existing flow through the plant. The grab sample was then added to the constant volume of Mill samples and at the end of each two-hour interval the total composite sample was utilized for an Imhoff cone study.

Analyses were made on each two-hour composite sample during the 24-hour period to determine the influence of the varying Metro sewage flow and characteristics. The laboratory data obtained for each two-hour composite are presented in Tables 15 and 16. Based upon the Imhoff cone settling data and the actual Metro and projected Mill flow rates, the total pounds of TSS and BOD theoretically removed in a full-scale primary clarifier for each two-hour interval was calculated. This information is presented in Table 17.

During the same 24-hour interval, six consecutive gravity settling column analyses were conducted on four-hour composite samples of Metro plus Mill 3. The results of the gravity settling column tests were again very disappointing. The data did not yield correlations between depth, detention time, overflow rate and percent removal of TSS.

The 15-minute grab sample of Metro sewage was added immediately to the particular composited mill samples rather than compositing the Metro sewage separately over the two-hour interval and then mixing the two components together prior to taking the samples for the Imhoff cone study. This procedure may have created an unrealistic pH adjustment which could affect the precipitation of dissolved solids.

The pilot plant primary clarifier data obtained between September 25,

PRIMARY CLARIFICATION INVESTIGATION
Imhoff Cone and Settlirg Column Analyses
Mill and Metro Combinations
February 26 - 27, 1969

SAMPLE COMPOSITION AND VOLUME

TWO-HOUR COMPOSITE SAMPLES FOR IMHOFF CONE ANALYSES

A.	Metro - 20 mgd	$\frac{\text{Meter Reading, mgd}}{\text{Average Daily Flow = 20 mgd}} \times \frac{*}{8}$ = size of 15 minute grab sample
B.	Mill 3 - 7 mgd	2.59 liters
	Metro - 20 mgd	7.41 liters*
C.	Mill 1 - 4 mgd	1.28 liters
	Mill 2 - 5 mgd	1.60 liters
	Mill 4 - 2.25 mgd	0.72 liters
	Metro - 20 mgd	6.40 liters *
D.	Mill 1 - 4 mgd	1.04 liters
	Mill 2 - 5 mgd	1.31 liters
	Mill 3 - 7 mgd	1.83 liters
	Mill 4 - 2.25 mgd	0.59 liters
	Metro - 20 mgd	5.23 liters*

FOUR-HOUR COMPOSITE SAMPLES FOR SETTLING COLUMN ANALYSES

E.	Mill 3 - 7 mgd	14.69 liters
	Metro - 20 mgd	$\frac{\text{Meter Reading, mgd}}{\text{Avg. Daily Flow = 20 mgd}} \times \frac{\text{42.06 liters*}}{16}$ = Size of 15 min. grab sam ple

*Total liters desired at existing average daily flow rate.

PRIMARY CLARIFICATION INVESTIGATION

Imhoff Cone Analyses
Mill and Metro Combinations
February 26-27, 1969
COMPOSITE SAMPLE

Interval	SAMPLE A pH a	pH b	TSS a	TSS b	VSS a	VSS b	BOD a	BOD b	Set Sludge b	% Red. TSS	% Red. BOD	SAMPLE B pH a	pH b	TSS a	TSS b	VSS a	VSS b	BOD a	BOD b	Set Sludge b	% Red. TSS	% Red. BOD
08-10	7.3	7.4	212	108	192	100	306	201	4.5	49.1	34.3	8.1	8.0	200	164	156	132	312	264	4.5	18.0	15.4
10-12	7.3	7.3	244	140	216	136	275	213	7.5	42.6	22.6	8.0	7.9	276	156	184	124	312	274	5.5	43.5	12.2
12-14	7.4	7.6	240	164	220	148	249	202	7.5	31.7	18.9	8.0	8.1	252	172	200	136	315	258	5.0	31.7	18.1
14-16	7.4	7.5	232	172	216	180	225	194	6.5	25.9	13.8	7.9	8.0	244	160	196	136	282	237	5.0	34.4	16.0
16-18	7.7	7.4	240	164	216	156	249	212	5.5	31.7	14.9	8.1	7.9	220	204	168	136	289	262	4.0	7.3	9.3
18-20	7.4	7.4	260	160	240	164	293	208	5.5	38.5	29.0	8.0	8.0	268	104*	208	88	330	248	4.0	61.2*	24.8
20-22	7.3	7.3	256	136	216	128	225	143	6.5	46.9	36.4	7.9	7.9	248	160	196	112	266	225	5.0	35.5	15.4
22-24	7.3	7.3	248	160	220	148	239	174	6.0	35.5	27.2	7.9	7.9	252	160	196	116	285	245	4.0	36.5	14.0
24-02	7.4	7.4	228	152	188	116	208	138	5.5	33.3	33.7	7.9	7.9	240	164	184	92	229	214	4.5	31.6	6.6
02-04	7.3	7.6	244	152	192	124	240	185	3.5	37.7	22.9	8.0	8.1	216	188	184	124	289	260	4.5	13.0	10.0
04-06	7.2	7.5	204	128	172	84	163	110	4.5	37.3	32.5	8.0	8.0	224	168	168	108	248	206	3.5	25.0	16.9
06-08	7.3	7.4	156	76	132	68	132	79	4.0	51.3	40.2	8.1	8.0	152	116	116	80	229	189	3.0	23.7	17.5

a. - Composite Sample Analyses
b. - Analyses of supernatant obtained 2 inches below liquid surface after 1/2 - hour settling
All concentrations - mg/l; all volumes - ml
* Estimated

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PRIMARY CLARIFICATION INVESTIGATION

Imhoff Cone Analyses
Mill and Metro Combinations
February 26-27, 1969
COMPOSITE SAMPLE

	SAMPLE C											SAMPLE D											
Time Interval	pH a	pH b	TSS a	TSS b	VSS a	VSS b	BOD a	BOD b	Set Sludge b	% Red. TSS	% Red. BOD	pH a	pH b	TSS a	TSS b	VSS a	VSS b	BOD a	BOD b	Set Sludge b	% Red. TSS	% Red. BOD
08-10	6.7	6.8	184	132	172	132	550	499	5.5	28.3	9.3	6.9	6.8	196	148	180	128	580	495	4.0	24.5	14.7
10-12	6.7	6.7	240	152	228	132	540	383	6.0	36.7	29.1	6.8	6.9	212	172	196	148	600	315	6.0	18.9	47.5
12-14	6.7	6.8	232	156	200	148	540	398	8.0	32.8	26.3	6.9	7.0	212	188	180	168	520	319	5.5	11.3	38.7
14-16	6.5	6.7	236	168	220	164	505	455*	5.0	28.8	9.9*	6.8	6.9	216	160	196	160	500	488	5.0	25.9	2.4
16-18	6.9	6.7	224	180	200	180	490	450	6.0	19.6	8.2	7.0	6.9	220	164	180	132	545	450	5.5	25.5	17.4
18-20	6.7	6.7	200	148	192	148	485	477	6.0	26.0	1.6	6.9	6.9	216	172	184	156	545	488	5.0	20.4	10.5
20-22	6.6	6.6	232	164	204	148	485	424	5.5	29.3	12.6	6.7	6.8	208	140	188	132	480	450	5.0	32.7	6.3
22-24	6.6	6.6	252	116	232	116	490	450	6.0	54.0	8.2	6.9	6.8	228	148	176	100	505	480	5.0	35.1	5.0
24-02	6.5	6.6	236	144	204	124	510	473	5.0	39.0	7.3	6.8	6.9	240	168	196	144	495	480	3.5	30.0	3.0
02-04	6.6	6.7	268	196	224	156	545	469	3.5	26.9	13.9	6.8	6.9	269	184	224	148	585	544	3.0	31.6	7.0
04-06	6.5	6.6	228	148	184	128	555	484	4.0	35.1	12.8	6.7	6.9	212	152	180	100	565	506	3.5	28.3	10.4
06-08	6.5	6.6	180	132	160	124	560	488	4.0	26.7	12.9	6.8	6.8	176	120	156	108	585	507	4.5	31.8	13.3

a. - Composite Sample Analyses
b. - Analyses of supernatant obtained 2 inches below liquid surface after 1/2 - hour settling
All concentrations - mg/l; all volumes - ml
* Estimated

PRIMARY CLARIFICATION
Imhoff Cone Analyses
Mill and Metro Combination
February 26-27, 1969

PROJECTED TOTAL SUSPENDED SOLIDS AND BOD REMOVAL IN FULL-SCALE

PRIMARY CLARIFICATION

Typical Calculation for Sample C:

1600-1800: Average GBMSD flow = 26.75 MGD; Industrial flow = 11.25 MGD; Total flow = 38.0 MGD

Projected Full-Scale TSS Removal During 2-Hour Interval-

38.0 MGD x 8.34 lbs/gal x 1/12 day x 224 ppm TSS (in) = 5916 lbs TSS (in)
38.0 MGD x 8.34 lbs/gal x 1/12 day x 180 ppm TSS (out) = 4754 lbs TSS (out)

Total lbs TSS Removed = 1162 lbs for 2-Hour Interval
Percent Removal = 19.6%

Sample Name	Lbs. In	Lbs. Out	Lbs. Removed	Percent Removal
	TOTAL SUSPENDED SOLIDS			
A. GBMSD	47092	29292	17800	37.8
B. GBMSD + Mill 3	61139	41813	19326	31.6
C. GBMSD + Mill 1, 2, 4	67243	45549	21694	32.3
D. GBMSD + All Mills	77255	56844	20411	26.4
	BIOCHEMICAL OXYGEN DEMAND			
A. GBMSD	47739	35178	12561	26.3
B. GBMSD + Mill 3	74007	62957	11050	14.9
C. GBMSD + Mill 1, 2, 4	154575	134866	19709	12.8
D. GBMSD + All Mills	192428	163542	28886	15.0

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1968 and January 31, 1969 were also utilized to project full-scale removals of BOD and TSS. This information is presented in Table 18. The data in this Table show the effect of varying the detention time and overflow rate on the removal of BOD and TSS.

The primary clarification data obtained between September, 1968 and February, 1969, show that increased BOD removals could be obtained when the combination of Metro plus all Mills was given primary clarification as compared to any other combinations studied. Based upon the 24-hour gravity settling column and Imhoff cone analyses, and upon the data obtained on the pilot plant primary clarifier between September 25, 1968 and January 31, 1969, the projected BOD and TSS removals for the combination of Metro plus all Mills were as follows:

BOD removal - approximately 10%
TSS removal - approximately 38%

At the time of this review it was contemplated that only Metro plus Mill 3 wastes would receive separate grit removal. Mills 1, 2 and 4 would join the grit chamber effluent for subsequent primary clarification.

Pilot Clarifier Studies - May 1 - July 31, 1969

Additional clarifier studies were conducted to obtain information on items which would have the greatest effect on cost estimates. Two of these items were:

1. The cost of sludge handling, which is dependent on the sludge concentration from the primary clarifier.
2. The effect of returning waste activated sludge to the primary clarifier.

A pilot clarifier for one activated sludge unit was constructed to study sludge characteristics and BOD and TSS removals when returning waste activated sludge. Details on unit design and test procedures are as follows:

1. Pilot Clarifier Design

   Internal diameter - 20 in.
   Sidewater depth - 72 in.
   Overflow rate - 540 GPD/sq ft
   Detention time - 2 hours

   A glass window in the side of the tank, approximately 2-1/2 in. wide by 60 in. high allowed the level of the sludge blanket to be observed.

PRIMARY CLARIFICATION

Projected Full-Scale Total Suspended Solids and BOD Removals
Based Upon Pilot Plant Primary Clarifier Operation
September 25, 1968 - January 31, 1969

Date	Desired Flow		Actual Flow		Det. Time Hours	Overflow Rate	Total Suspended Solids				Biochemical Oxygen Demand			
	Pilot Plant	Equiv. Full-Scale	Pilot Plant	Equiv. Full-Scale					Removed				Removed	
1968-69	L/D	MGD	L/D	MGD	Hours	GPD/sq ft	mg/l	lbs/day	lbs/day	%	mg/l	lbs/day	lbs/day	%
9/25-10/14	17908	38.25	16656	35.58	2.49	480	206	61121 (in)			562	166747 (in)		
							128	37978 (out)	23143	37.9	528	156659 (out)	10088	6.0
10/15-11/1	8954	38.25	8678	37.07	4.79	250	243	75129 (in)			570	176228 (in)		
							127	39265 (out)	35864	47.7	473	146238 (out)	29990	17.0
11/2-11/21	8954	38.25	7818	33.40	5.31	225	236	65734 (in)			679	189123 (in)		
							118	32867 (out)	32867	50.0	598	166562 (out)	22561	11.9
11/22-12/11	13431	38.25	13735	39.12	3.02	396	237	77315 (in)			568	185296 (in)		
							153	49912 (out)	27403	35.4	507	165396 (out)	19900	10.7
12/12-1/4	17908	38.25	17018	36.35	2.44	490	248	75181 (in)			593	179768 (in)		
							151	45776 (out)	29405	39.1	565	171280 (out)	8488	4.7
1/5-1/31	13431	38.25	15098	43.00	2.75	435	218	78174 (in)			494	177148 (in)		
							117	41956 (out)	36218	46.3	449	161011 (out)	16137	9.1

Full-Scale Influent Ratio

Mill 1 -	4.0 mgd
Mill 2 -	5.0 mgd
Mill 3 -	7.0 mgd
Mill 4 -	2.25 mgd
GBMSD -	20.0 mgd
Total -	38.25 mgd

Primary Clarifier Dimensions

Diameter------------3.5 ft
Sidewater Depth-----6.7 ft
Surface Settling Area-9.2 sq ft
Volume------------1730 liters

Table 18

2. The influent to the pilot clarifier was the same combined waste (all Mills plus Metro) being fed to the large pilot plant primary clarifier.

3. Grab samples of the effluent were taken on the odd hours, 7 days a week, and composited over 24 hours for analyses of BOD and TSS removal efficiency.

4. Waste activated sludge from either the contact stabilization control plant or the Kraus control plant was fed continuously to the pilot clarifier.

5. The waste activated sludge fed to the pilot clarifier each day was that collected during the previous day. The waste activated sludge was continuously mixed while being fed to the pilot clarifier.

6. The pilot plant operator made sludge draws, up to 8 times daily, to maintain a 12-inch sludge blanket. The draws did not exceed 4 gallons. Based upon the volume drawn, proportional samples of the pilot clarifier sludge were collected and composited daily for TSS and VSS analyses. The sludge level variations were recorded on the even hours, 7 days a week.

The flow schematic for the operation of the pilot clarifier is shown in Figure 8.

The pilot clarifier was started up on April 14, 1969. Waste activated sludge from the Kraus-control plant was fed to the pilot clarifier, beginning April 22. The average, maximum and minimum values for each operating parameter are presented in Table 19. A comparison of the pilot and primary clarifier operations is presented in Table 20.

The following conclusions were made on the effect of adding waste activated sludge to the pilot clarifiers:

1. No effect on TSS removal was apparent.
2. Unfiltered BOD increased in the effluent.
3. Clarifier sludge concentration decreased. However, this procedure would significantly reduce the total volume of waste activated sludge to be handled in subsequent processes.

Due to the wide fluctuation in sewage flow to the GBMSD treatment plant the use of primary clarification facilities as a reliable method for thickening waste activated sludge cannot be justified. During a high flow condition the thickened solids in the primary clarifiers could possibly

PRIMARY CLARIFICATION

PILOT CLARIFIER FLOW SCHEMATIC
MAY, JUNE, JULY, 1969

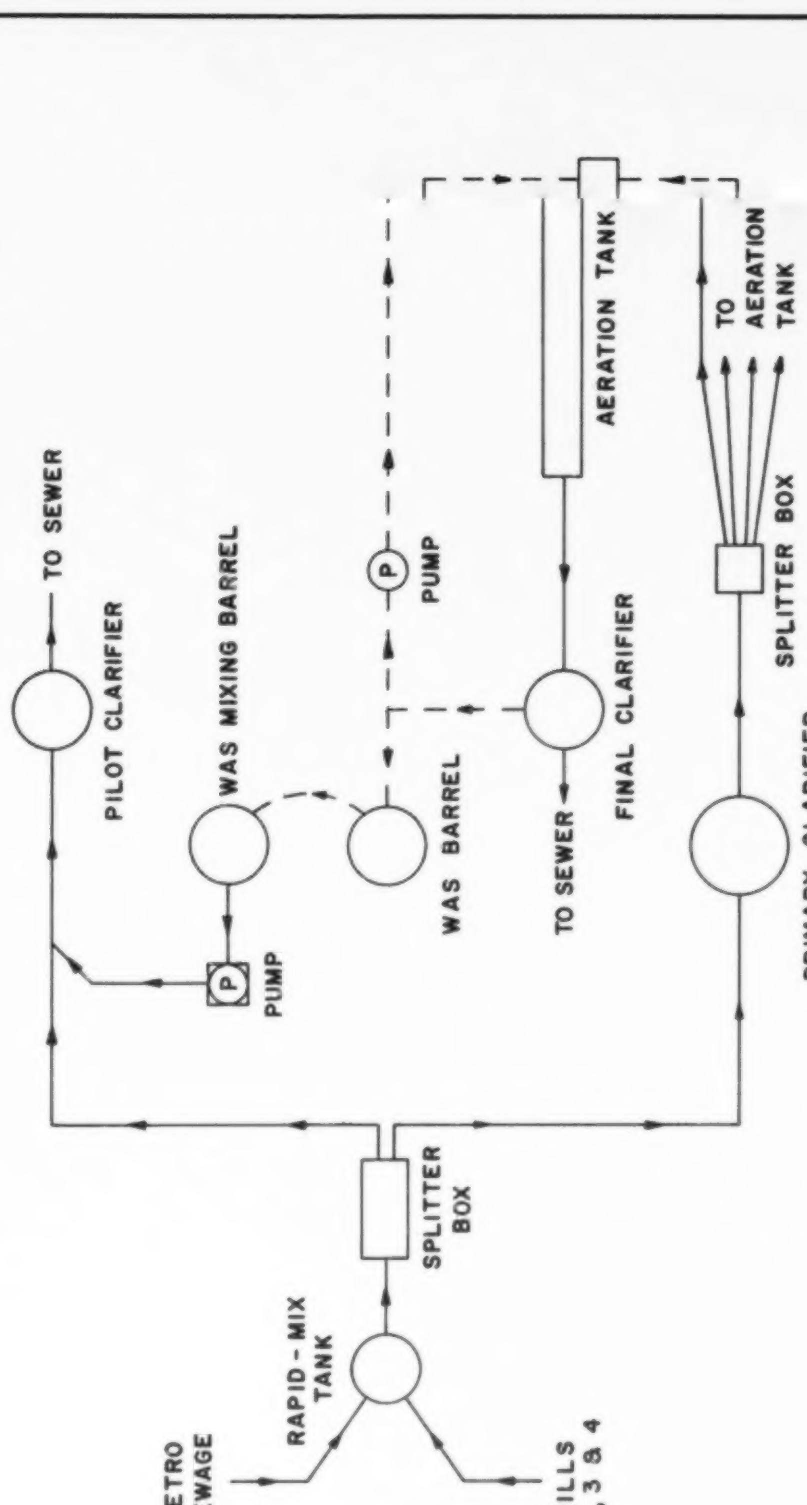
METRO SEWAGE
MILLS 1,2,3 & 4
RAPID - MIX TANK
SPLITTER BOX
PUMP
P
WAS MIXING BARREL
PILOT CLARIFIER
TO SEWER
WAS BARREL
P
PUMP
TO SEWER
FINAL CLARIFIER
AERATION TANK
PRIMARY CLARIFIER
SPLITTER BOX
TO AERATION TANK

FIGURE 8

PRIMARY CLARIFICATION INVESTIGATION
Pilot Clarifier Operation
May 1 - July 31, 1969

MONTH		Q fwd	WAS feed	Q total	WAS added grams/day		EFFICIENCY ANALYSIS, mg/l Tot. Sus. Sol.			Vol. Sus. Sol.			Unfilt. BOD			color unit	$S^=$	RAW PILOT SLUDGE Vol. Solids Anal. mg/l		
		L/D	L/D	L/D	TSS	VSS	PI	PE	%red	PI	PE	%red	PI	PE	%red	PE	PE	L/D	TSS	VSS
May	Avg.	4270	65	4340	1080	874	233	164	29.6	184	121	34.2	567	581	--	320	--	26.6	36029	29664
	Max.	4958	208	4852	3236	2692	456	296	59.0	356	204	61.1	689	674	15.7	469		121.1	60696	53368
	Min.	2999	0	3041	0	0	104	88	0	96	70	0	482	450	0	264		0	19272	16064
June	Avg.	4333	85	4415	1072	902	229	161	29.7	178	127	28.7	490	493	--	319	.293	23.8	39708	32703
	Max.	4958	136	5117	2502	1920	336	284	75.5	248	196	67.9	623	742	22.9	507	.500	94.6	46328	38120
	Min.	3047	19	3138	203	175	108	44	0	80	36	0	340	380	0	208	.0398	0	32968	26987
July	Ave.	4173	54	4227	586	483	218	167	23.4	176	133	24.4	486	477	1.9	248	.574	19.2	35216	29527
	Max.	5095	133	5167	1392	1176	288	248	48.6	248	236	45.8	615	629	18.2	302	.794	109.8	54652	44456
	Min.	3620	0	3718	0	0	108	92	0	88	52	0	363	380	0	191	.500	0	29300	23564

WAS Feed: May 1 - June 3, 1969; Kraus - Control waste activated sludge.

June 4 - July 31, 1969; Contact Stabilization-Control waste activated sludge.

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PRIMARY CLARIFICATION INVESTIGATION

Comparison of Pilot Clarifier and Primary Clarifier Operation
May 1 - July 31, 1969

MONTH		WAS Feed L/D	Total Suspended Solids mg/l			Volatile Suspended Solids mg/l			BOD, mg/l			Sludge Draws	
			PI	Effluent		PI	Effluent		PI	Effluent		% TSS	
				Primary	Pilot		Primary	Pilot		Primary	Pilot	Primary	Pilot
May	Avg.	65	233	175	164	184	121	121	567	553	581	5.5	3.8
	Max.	208	456	312	296	356	192	204	689	669	674	6.4	6.1
	Min.	0	104	68	88	96	80	70	482	415	450	4.5	1.9
June	Avg.	85	229	186	161	178	136	127	490	463	493	6.7	4.0
	Max.	136	336	304	284	248	192	196	623	617	742	10.1	4.6
	Min.	19	108	104	44	80	56	36	340	349	380	5.3	3.3
July	Avg.	54	218	165	167	176	131	133	486	433	477	7.3	3.7
	Max.	133	288	220	248	248	184	236	615	567	629	11.4	5.5
	Min.	0	108	60	92	88	52	52	363	289	380	3.7	2.9

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be flushed into the secondary system, resulting in subsequent problems in that unit. However, the data obtained on the pilot clarifier operation did show that, under normal flow conditions, return of the waste activated sludge to the primary clarification units can significantly increase the concentration of waste activated sludge without causing serious detrimental effects on the primary effluent. Therefore, it is recommended that piping be included in the full-scale plant to permit the return of waste activated sludge to the primary clarifier if so desired.

Pilot Clarifier Studies - September 1 through October 19, 1969

Additional studies conducted with Pilot Plant A connected directly to the pilot clarifier were as follows:

1. Elimination of Mill 3 effluent to Pilot Plant A.
2. Increased hydraulic loadings on the primary and secondary processes to approximate a storm flow condition.
3. Bypass Mill 1, 2 and 4 wastes around primary clarification directly to the secondary system.

Between September 1 and October 19, Pilot Plant A was operated such that Metro sewage only was receiving primary treatment and Mill 1, 2 and 4 wastes were added to the pilot clarifier effluent. Composite sampling of Metro flow, pilot clarifier effluent and Plant A aeration tank feed was begun for routine laboratory analyses.

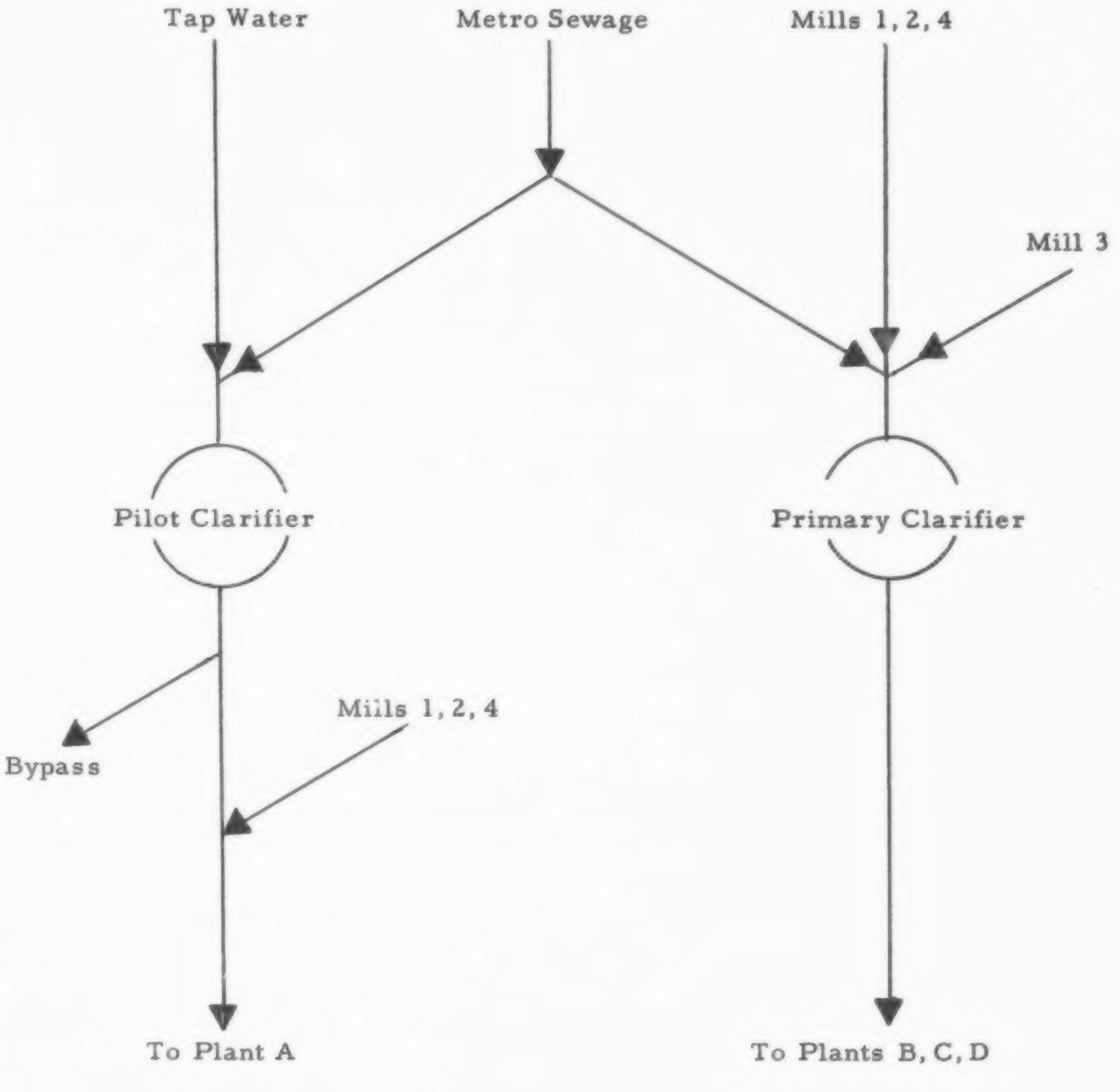
The high-flow studies began October 3 by increasing the Metro sewage flow. Between October 7 and October 19, tap water was added to the Metro sewage to reduce the BOD to approximately 100 mg/l, simulating a storm flow condition. The flow schematic illustrating the operation of the pilot clarifier under storm flow conditions is presented in Figure 9. The average, maximum and minimum pilot clarifier operating values for September 1 through October 19 are presented in Table 21.

Summary of Primary Clarification Studies

This concluded the special studies to evaluate various options for primary clarification. The decisions regarding primary clarification which were utilized in the final cost estimate are as follows:

1. Only Metro sewage would normally receive primary clarification.
2. The mill effluents would not be discharged into existing interceptor sewers but would be conveyed to the treatment plant in a separate interceptor sewer system.

PILOT-PRIMARY CLARIFIER FLOW SCHEMATICS
September 1 through October 19, 1969


Tap Water
Metro Sewage
Mills 1, 2, 4
Mill 3
Pilot Clarifier
Primary Clarifier
Bypass
Mills 1, 2, 4
To Plant A
To Plants B, C, D

PRIMARY CLARIFICATION

Pilot Clarifier Operation
September 1 through October 19, 1969

		Flow to Pilot Clarifier						Pilot Clar. Influent				Pilot Clarifier Effluent						Pilot Clarifier		
		Liters/Day																Sludge Draws		
		Mills							mg/l				mg/l		%	mg/l	%	Vol.	mg/l	
1969		1	2	3	4	Metro	Tot.	pH	TSS	VSS	BOD	pH	TSS	VSS	Red.	BOD	Red.	L/D	TSS	VSS
9/1-9/30	Ave.	0	0	0	0	3516	3516	7.6	298	249	286	7.6	133	113	55.4	237	17.1	6.4	42583	33618
	Max.					4575	4575	7.8	672	540	560	7.7	192	176	82.9	387	56.4	15.1	69460	57464
	Min.					2680	2680	7.1	150	142	102	7.2	66	58	29.4	95	0	0	23308	17172
10/1-10/6	Ave.	531	531	0	64	4649	5775	6.9	507	435	245	7.2	120	92	76.3	262	----	4.0	39833	34261
	Max.	531	531	0	64	5780	6906	6.9	1108	972	336	7.2	188	188	87.0	334	15.1	7.6	43748	37092
	Min.	531	531	0	64	3226	4352	6.9	164	140	120	7.2	82	62	29.9	116	0	1.9	35644	30948
10/7-10/19	Ave.	531	531	0	64	7048	8175	7.2	128	113	117	7.3	61	54	52.3	232	----	7.9	23762	19890
	Max.	531	531	0	64	10863	11989	7.4	239	209	189	7.3	160	92	85.3	203	72.2	56.8	42480	35264
	Min.	531	531	0	64	4846	5972	7.0	79	68	33	7.2	14	34	0	22	0	1.9	7280	6240

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3. Piping would be installed to allow the Mill wastes to be introduced into or bypass primary clarification as desired.
4. Piping would be installed to allow waste activated sludge to be returned to the primary clarifier if so desired.

(Cost distribution studies conducted after completion of the pilot plant studies indicated that it was more economical to treat only the Metro sewage in primary clarification and convey the Mill wastes directly to the secondary system.)

INTRODUCTION TO PILOT PLANT RESEARCH PROGRAM

Pilot plant research was conducted between February 6, 1968 and January 31, 1969 and again between February 24, 1969 and December 15, 1969. During these two time intervals the pilot plants operated continuously 24-hours a day, seven days a week, totaling 22 months of continuous operation.

The research program is divided into four major phases as follows:

PHASES OF PILOT PLANT RESEARCH

PHASE	STUDY	DATES
I	Startup--Filamentous Biological Growths	February 6, 1968 to August 31, 1968
II	Statistical Experimental Design	September 1, 1968 to January 31, 1969
III	Contact Stabilization and Kraus Detailed Studies	February 24, 1969 to July 31, 1969
IV	Contact Stabilization Design and Operating Parameters--Solids Handling Studies	August 1, 1969 to December 15, 1969

Each Phase will be discussed individually in the following sections of this report.

PILOT PLANT RESEARCH - PHASE I

Pilot Plant Startup

The four activated sludge pilot plant units were started up on Metro sewage on February 6, 1968. The flow arrangement for the four processes at startup is shown in Figure 10. All units were operated as conventional activated sludge units during buildup of the mixed liquor suspended solids.

The first load of mill waste was delivered February 16. The industrial flows were fed to the pilot plants (which were at about 2500 mg/l MLTSS) at a gradually increasing rate as follows:

Date	Mill Wastes to Pilot Plants
February 16	25% of Full Value
February 20	50% of Full Value
February 23	75% of Full Value
February 27	100% of Full Value

At each industrial flow setting the Metro sewage flow was adjusted to maintain a continuous 4.0 gpm flow to the splitter box. The mill and Metro wastes were fed at constant rates during Phase I. Three of the units were subsequently converted from conventional (C) to contact stabilization (CS), step aeration (SA), and Kraus (K) activated sludge processes.

It was necessary to continuously add defoamer to each aeration tank shortly after startup. Diffuser stones being used for aeration were removed from several cells in an effort to reduce the foaming problem and were replaced with a plastic pipe extending to the bottom of the respective cells. This provided adequate dissolved oxygen and eliminated the foaming problems in those particular cells. On April 16, all remaining diffuser stones were removed from the aeration sections and replaced with plastic pipe.

A thick gelatinous material was present on the surface of the stones which were removed. When viewed under a microscope, this material did not resemble any growths observed in previous samples from the pilot plants. It is not known why this growth tended to accumulate on the surface of the stones.

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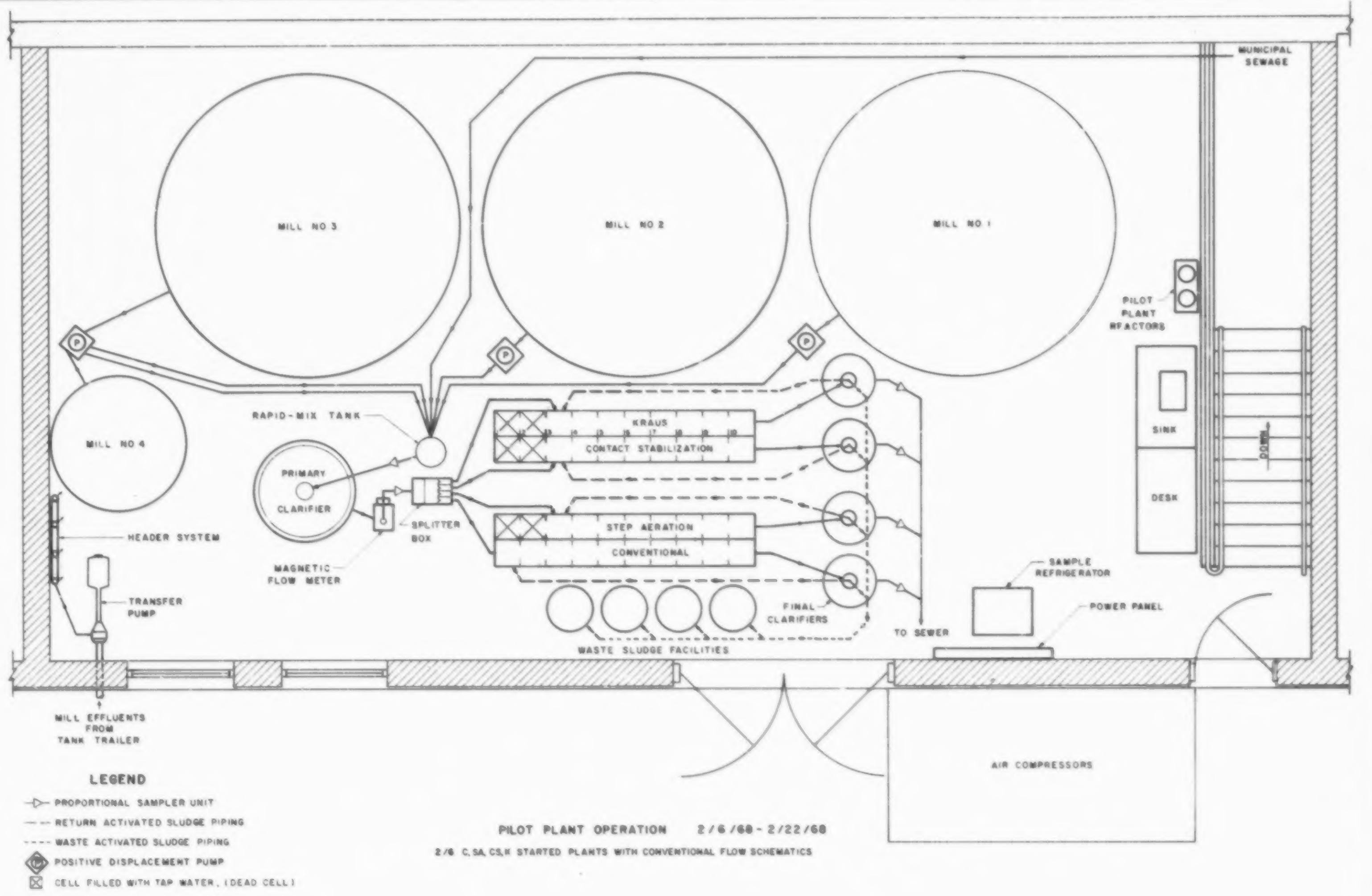
MUNICIPAL SEWAGE
MILL NO 3
MILL NO 2
MILL NO 1
MILL NO 4
PILOT PLANT REACTORS
SINK
DESK
DOWN
RAPID-MIX TANK
KRAUS
CONTACT STABILIZATION
STEP AERATION
CONVENTIONAL
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
FINAL CLARIFIERS
TO SEWER
WASTE SLUDGE FACILITIES
SAMPLE REFRIGERATOR
POWER PANEL
AIR COMPRESSORS
MILL EFFLUENTS FROM TANK TRAILER
LEGEND
PROPORTIONAL SAMPLER UNIT
RETURN ACTIVATED SLUDGE PIPING
WASTE ACTIVATED SLUDGE PIPING
POSITIVE DISPLACEMENT PUMP
CELL FILLED WITH TAP WATER, (DEAD CELL)

PILOT PLANT OPERATION   2/6/68 - 2/22/68

2/6 C, SA, CS, K STARTED PLANTS WITH CONVENTIONAL FLOW SCHEMATICS

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC   CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE $\frac{3}{16}'' = 1'\text{-}0''$

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 10 PAGE 101

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The desired full-flow operating conditions were as follows:

Pilot Plant Operating Parameters

February 27 - May 30, 1968

Plant	Q, gpm	R/Q	Cell 10 MLVSS mg/l	RAS-TSS mg/l	Detention Time, Hours (R + Q)	F/M
C	1.0	1.0	4000	9000	3.8	0.48
SA	1.0	1.0	4000	9000	3.8	0.47
CS	1.0	1.0	4000	9000	3.0 - Stab. 1.5 - Contact	0.40
K	1.0	1.0*	4000	9000	21.4 - Nitrify. 1.5 - Contact	0.37

*Kraus RAS flow: 85% to contact section, 15% to nitrifying section; digester supt. addition = 0.015 x Q.

Estimated PE-BOD - 600 mg/l; dissolved oxygen - 2 mg/l; no nutrient feed.

Filamentous Microorganisms

During February, samples of mixed liquor from the laboratory reactors were analyzed by Dr. G. J. Farquhar(13, 14), University of Wisconsin, Madison. The dominant feature of the sample from Reactor 4 was the presence of lobate, finger-like growths associated with some of the floc, which consisted of bacterial cells incased in a hyaline capsule. This is characteristic of a condition called zoogloeal bulking. There were very few filamentous microorganisms present in this sample.

The dominant feature of the mixed liquor samples from Reactor R5 was a substantial growth of filamentous microorganisms associated with all sizes of floc. The filamentous microorganisms was identified as a species of the genus Thiothrix. Identifying factors were it's ability to store sulfur in a sulfide environment and also certain morphological characteristics such as base tip differentiation.

Based upon Dr. Farquhar's previous research, it was suggested that preaeration or prechlorination be considered to reduce the sulfide content in the feed to the reactor. Dr. Farquhar's report also stated that if zoogloeal bulking presented a problem, then the recommendations of Heukelekian and Weisberg(15) should be followed. These recommendations consisted of (1) reducing the food to microorganism ratios at normal mixed liquor suspended solids concentrations and (2) chlorination of the return activated sludge. However, the presence of zoogloeal growths was noted in the reactor for several months and did not cause any apparent settling problems.

Through February 22, no filaments were observed in the pilot plant aeration units although unidentified filamentous growths were observed in Mill 3 and 4 waste storage tanks. Filamentous microorganisms were first reported in the pilot plant aeration units on February 27.

Due to uncontrollable rising sludge blankets in the final clarifiers, mixed liquor solids were lost over the final clarifier weirs in the C, SA and K units beginning March 5. On March 11, the mixed liquor solids in the CS unit were also being lost over the final clarifier weir.

On March 7, mixed liquor and mill waste samples were analyzed by Dr. Farquhar; the analyses were as follows:

Pilot Plant	Filament Concentration	Ecology
Conventional	Excessive	*Sphaerotilus*; *Thiothrix* - trace.
Step Aeration	Moderate	*Sphaerotilus*; *Thiothrix* - trace.
Contact Stabilization	Slight	*Thiothrix* and *Sphaerotilus* in about equal numbers.
Kraus	Moderate	*Thiothrix*; *Sphaerotilus* - trace.
Storage Tanks		
Mill 3	None	
Mill 4	None	

Additional samples of aeration tank, laboratory reactor, and mill waste storage tank contents were analyzed on March 14 by Dr. Farquhar. The results of these analyses are presented in Table 22.

MICROBIOLOGICAL ANALYSES - PHASE I

March 14, 1968

Sample	General Ecology	Dominant Species	
C-10*	Excessive filaments.	*Sphaerotilus*	Trace of *Beggiatoa* and *Thiothrix*
SA-10	Excessive filaments; a few stalked protozoa.	*Sphaerotilus*	Some *Thiothrix*
CS-10	Slight filamentous growths; small floc; a few stalked flagellates.	*Thiothrix*	Traces of *Sphaerotilus* and *Beggiatoa*
K-10	Moderate filaments; large floc; very few protozoans.	*Thiothrix* and *Sphaerotilus*	Trace of *Beggiatoa*
R-1	Slight amount of filament; excessive fibrous debris; many stalked protozoans; sludge worms.	Unknown species dominant, probably *Sphaerolitus* species	Trace of *Beggiatoa* and fungi
R-5	Excessive filaments; many worms; some stalked protozoans.	Unknown species, as in R-1, dominant; exists in bundles.	Trace of *Thiothrix*
M-1	Trace of filaments, some fibers.		
M-2	Moderate fungus growth; other single cell life.		
M-3	Very few filaments.		
M-4	No filaments; some fibers; many single cells.		

* Cell 10 of the conventional unit.

Samples of C-10*, SA-10, CS-6, CS-10, K-6, and K-10 mixed liquor were sent to E. F. Houghton and Co., Philadelphia, Pa., March 27 for microbiological analyses. The following conclusions were made:

> "In general, the bacterial plate counts for the samples from the six locations were fairly uniform. The samples were relatively low in coliform organisms, with sizable numbers of the genus *Proteus*. All of the samples had large numbers of sulfur bacteria of the genera *Thiothrix* and *Beggiatoa*. Numberous cultures of *Zoogloea ramigera* were also noted."

An important point in these conclusions was that *Sphaerotilus natans* was not observed in significant quantities in the samples.

Samples from Cell 10 of the conventional and contact stabilization units were submitted to Buckman Laboratories, Inc., Memphis, Tenn. on April 4 for biological analyses. The report on these analyses is summarized as follows:

> "The two activated sludge samples were received in thermos bottles, but at temperatures above those which are necessary to prevent decomposition. A large population of sulfate-reducing bacteria had developed."
>
> Contact stabilization - Cell 10: "This sludge appeared to have a highly diversified microflora which contained considerable amounts of filamentous microorganisms. The filamentous microorganisms primarily associated with this sludge were *Sphaerotilus natans*, *Beggiatoa spp.*, *Thiothrix spp.*, and fungus (believed to be *Phytophthora sp.*).
>
> *Thiothrix* appeared to be the predominant influence on bulking of the sludge, as many gelatinous hold-fasts were observed in which true bacteria agglomerates were attached. However, the influence of *S. natans* and *Beggiatoa* were significant contributors to the bulking process.
>
> Conventional - Cell 10: "This sludge appeared to have more finely dispersed particles but much less filamentous microorganisms. There was no fungus observed in this sludge; however, the same type of filamentous bacteria were observed. In addition, there appeared to be a significant amount of filamentous algae (*Oscillatoria* and *Ulothrix*)".

---

* i.e., Cell 10 of the conventional unit

All units became infested with filamentous microorganisms during March causing sludge bulking and subsequent loss of biological solids in the final effluents. The predominant filaments in the conventional unit were identified as *Sphaerotilus natans*. In an effort to control this microorganism, the mixed liquor dissolved oxygen level was varied from very low to high values. This approach had no apparent success. By the end of the month, the filament population had changed from predominantly *Sphaerotilus natans* to predominantly *Thiothrix*.

In the step aeration unit the predominant filament initially was *Sphaerotilus natans* but likewise changed to predominantly *Thiothrix* by the end of March. Dissolved oxygen variations were also utilized as a possible control with no apparent success. However, the change from *Sphaerotilus natans* to *Thiothrix* occurred prior to the variation of the dissolved oxygen content.

The filamentous growths in the contact stabilization unit were evenly divided between *Sphaerotilus natans* and *Thiothrix* early in March. *Thiothrix* became the predominant filamentous microorganism by April 1.

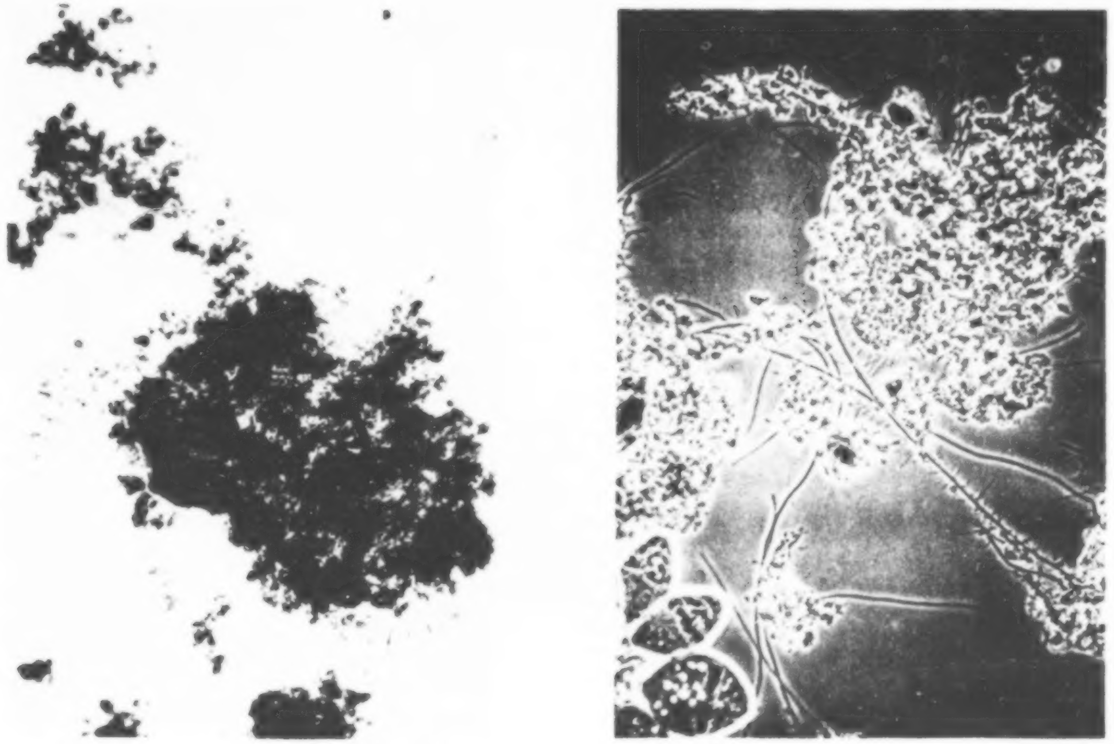
The Kraus unit, which was not truly a Kraus process since the addition of digester supernatant was not started until March 27, was infested predominantly with *Thiothrix* throughout the month.

In order to better understand the relationship between sulfide concentrations and the presence of filaments, a specific ion probe was obtained to measure the sulfide concentrations in the various pilot plant streams. In addition, in order to be able to specifically identify the filamentous microorganisms, and to routinely monitor the aeration units, a phase contrast microscope with attached polaroid camera was ordered. A report entitled "Identification and Classification of Filamentous Microorganisms in Activated Sludge"(16) was prepared for use by the project staff. (See Appendix B for routine procedure used for microbiological analyses.)

Arrangements were made with Dr. H.H. Heitzman, St. Mary's Hospital, Green Bay to take photographs of the mixed liquor samples, utilizing phase contrast microscopy, until a microscope was obtained. Microphotographs obtained April 15 are shown in Figures 11 to 12. The filamentous organisms containing sulfur granules are quite clearly shown in these photographs.

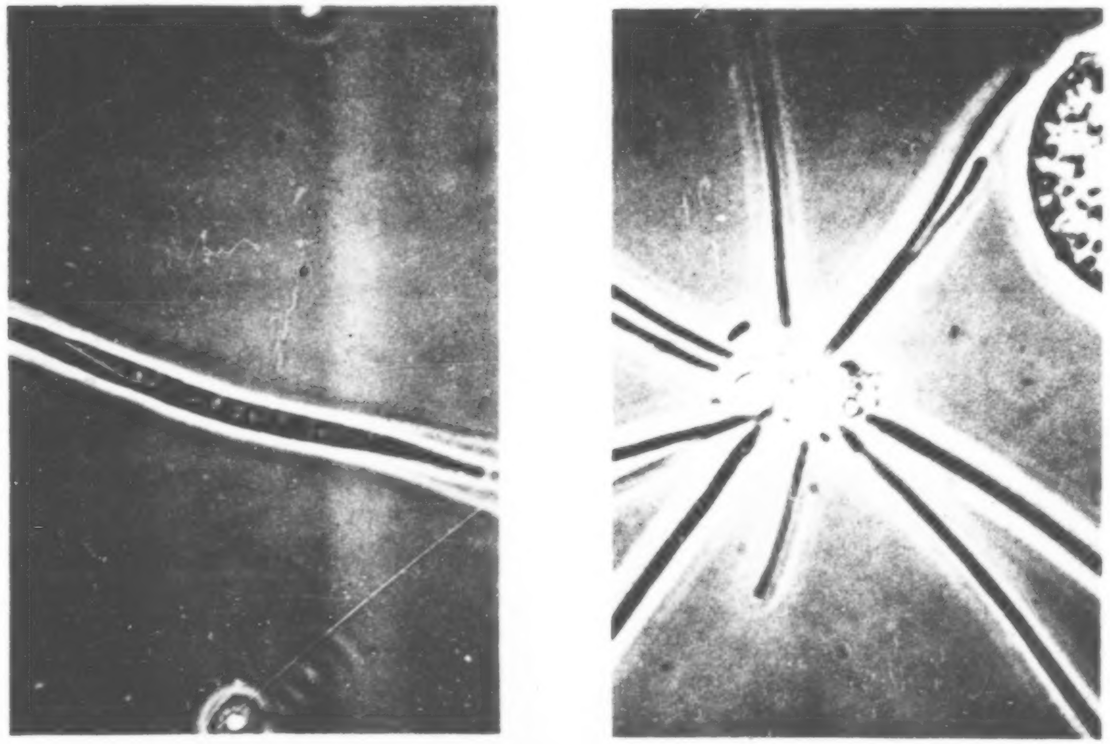
Operational Variations to Control Filamentous Microorganisms

During Phase I, many variations in plant operation were made in an



TYPICAL ACTIVATED SLUDGE FLOC.

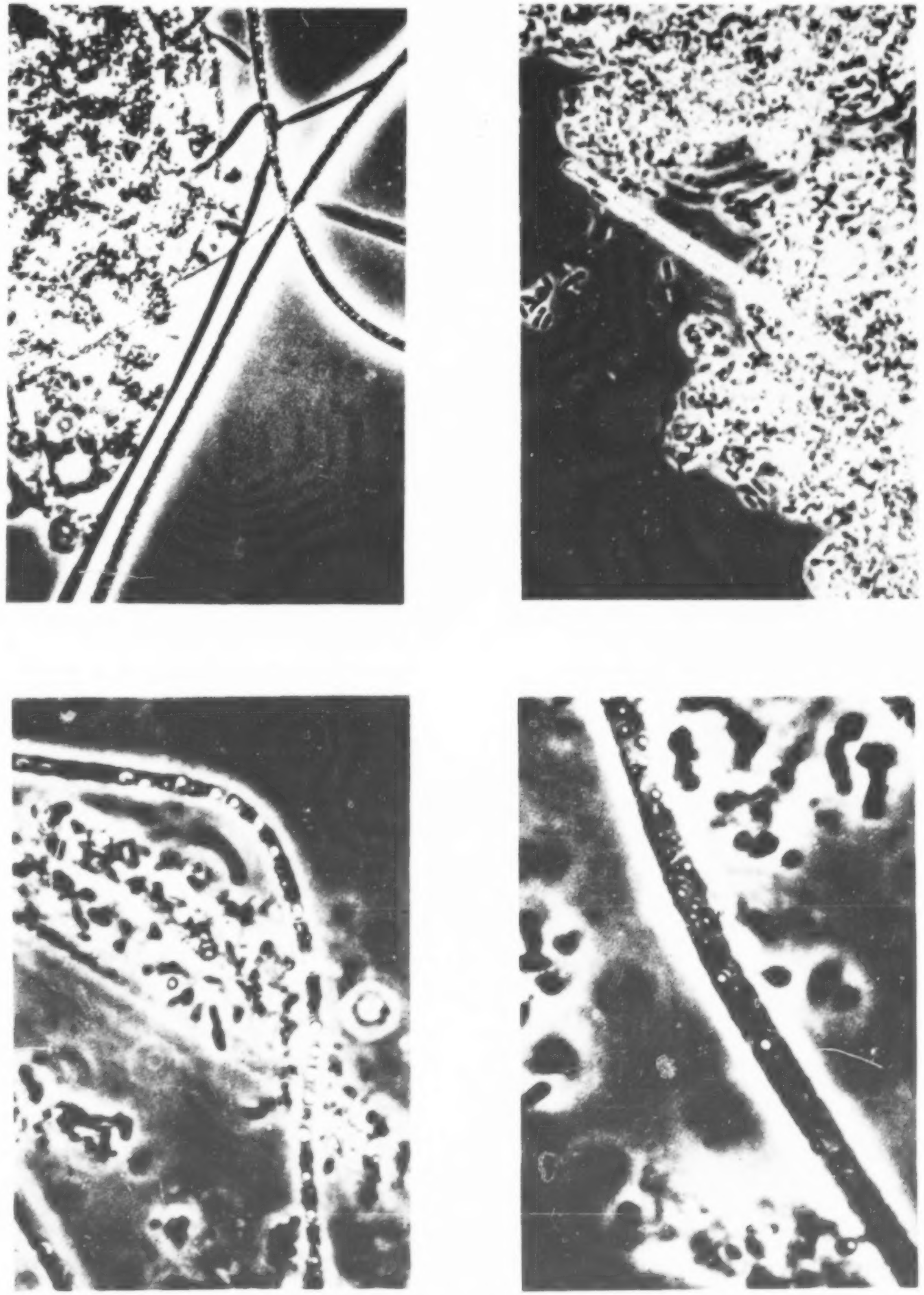
FILAMENTOUS MICROORGANISMS



SEGMENTED FILAMENT

FILAMENT ROSETTE

BIOLOGICAL MICROPHOTOGRAPHS FIGURE 11 PAGE 107



FILAMENTOUS BACTERIA CONTAINING SULFUR GRANULES

FIGURE 12 PAGE 109

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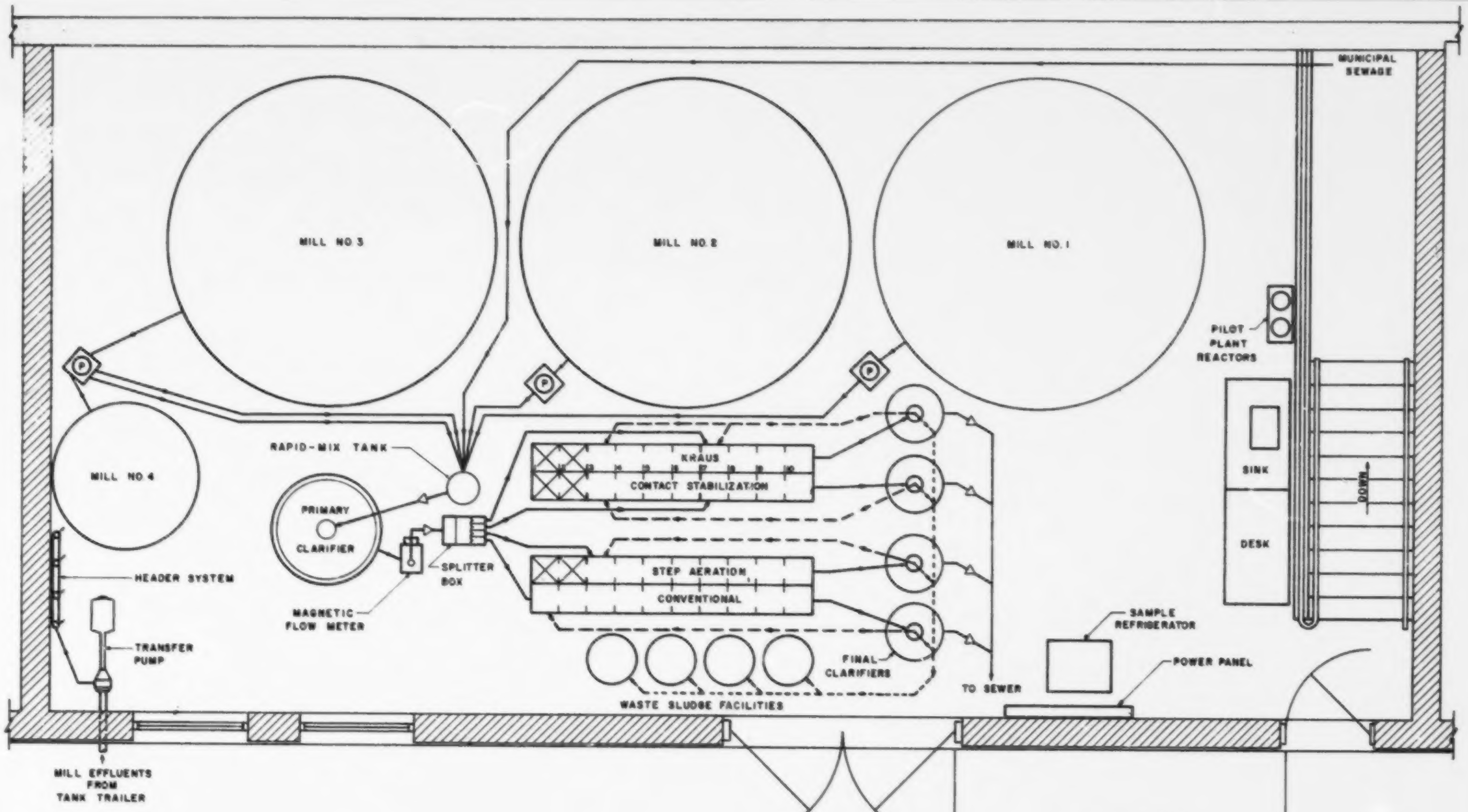
effort to eliminate filamentous microorganisms. Some of the operational features instituted were:

1. Variation in dissolved oxygen content in mixed liquor.
2. Preaeration of primary effluent.
3. Bypassing primary effluent to maintain desired F/M ratios.
4. Addition of nitrogen and phosphorus to maintain desired BOD:N:P ratios.
5. Shock chlorination of aeration tanks and final clarifier contents.

Changes in the pilot plant flow schematics during Phase I are shown in Figures 13-16. A summary of these and other operational changes is presented in Table 23.

The graphical relationships between primary effluent sulfide concentration, RAS sulfide concentration, BOD:N:P ratio, preaeration of primary effluent, mixed liquor dissolved oxygen level, shock chlorination and filament concentration are presented in Figures 17-20 for each of the four pilot plants. These graphs for the period from March 1 to August 31 illustrate the various operational changes made in an effort to minimize the filamentous bulking problems. The following comments apply to these figures:

1. The sulfide analyses of the primary effluent and RAS are not complete due to problems in developing procedures for sulfide measurement. These sulfide data were obtained using a single junction sulfide probe resulting in values which would tend to be lower than that actually existing in the given sample.
2. The desired BOD:N and BOD:P ratios are shown by a solid line. The numbers below the solid lines are the average ratios for the time interval shown. For example, the average BOD:N and BOD:P ratios for the conventional unit during July were 7.0 and 1.5, respectively.
3. The dissolved oxygen levels shown were the values that were maintained, as closely as possible, for the aeration units.
4. The letters N, T, S, M, X and E in the "Filaments" section represent none, trace, slight, moderate, excessive and epidemic concentrations, respectively.


MUNICIPAL SEWAGE
MILL NO. 3
MILL NO. 2
MILL NO. 1
MILL NO. 4
P
PILOT PLANT REACTORS
SINK
DESK
DOWN
RAPID-MIX TANK
PRIMARY CLARIFIER
KRAUS
CONTACT STABILIZATION
STEP AERATION
CONVENTIONAL
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
FINAL CLARIFIERS
TO SEWER
WASTE SLUDGE FACILITIES
SAMPLE REFRIGERATOR
POWER PANEL
AIR COMPRESSORS
MILL EFFLUENTS FROM TANK TRAILER

LEGEND

- —▷— PROPORTIONAL SAMPLER UNIT
- — — RETURN ACTIVATED SLUDGE PIPING
- ---- WASTE ACTIVATED SLUDGE PIPING
- ◈ POSITIVE DISPLACEMENT PUMP
- ☒ CELL FILLED WITH TAP WATER, (DEAD CELL)

PILOT PLANT OPERATION 2/23/68 - 3/19/68

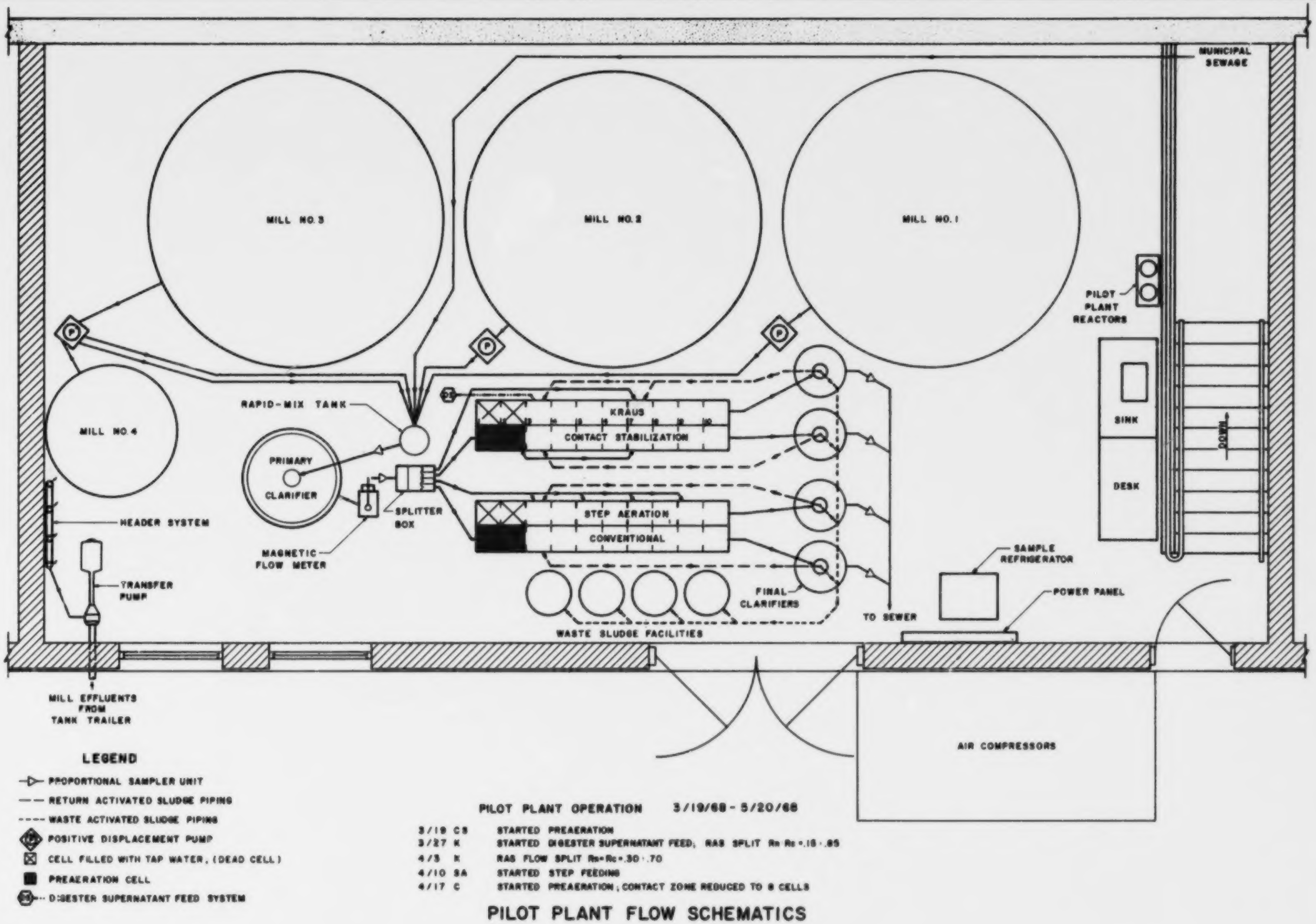
2/23 CS	FEED FLOW TO CELL 7
2/26 K	FEED FLOW TO CELL 7
3/19 K	RAS FLOW SPLIT Rk : Rc = .50 : .50

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE $\frac{3}{16}$" = 1'-0"

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 13 PAGE 111


MUNICIPAL SEWAGE
MILL NO.3
MILL NO.2
MILL NO.1
MILL NO.4
PILOT PLANT REACTORS
SINK
DESK
DOWN
P
RAPID-MIX TANK
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
KRAUS
CONTACT STABILIZATION
STEP AERATION
CONVENTIONAL
FINAL CLARIFIERS
WASTE SLUDGE FACILITIES
TO SEWER
SAMPLE REFRIGERATOR
POWER PANEL
AIR COMPRESSORS
MILL EFFLUENTS FROM TANK TRAILER

LEGEND

- —▷— PROPORTIONAL SAMPLER UNIT
- — — RETURN ACTIVATED SLUDGE PIPING
- - - - - WASTE ACTIVATED SLUDGE PIPING
- ◈ POSITIVE DISPLACEMENT PUMP
- ☒ CELL FILLED WITH TAP WATER, (DEAD CELL)
- ■ PREAERATION CELL
- ⬡ DIGESTER SUPERNATANT FEED SYSTEM

PILOT PLANT OPERATION 3/19/68 - 5/20/68

3/19 CS	STARTED PREAERATION
3/27 K	STARTED DIGESTER SUPERNATANT FEED; RAS SPLIT Rn Rc = .15 · .85
4/3 K	RAS FLOW SPLIT Rn=Rc = .30 · .70
4/10 SA	STARTED STEP FEEDING
4/17 C	STARTED PREAERATION; CONTACT ZONE REDUCED TO 8 CELLS

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC. CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE 3/16" = 1'-0"

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 14 PAGE 113

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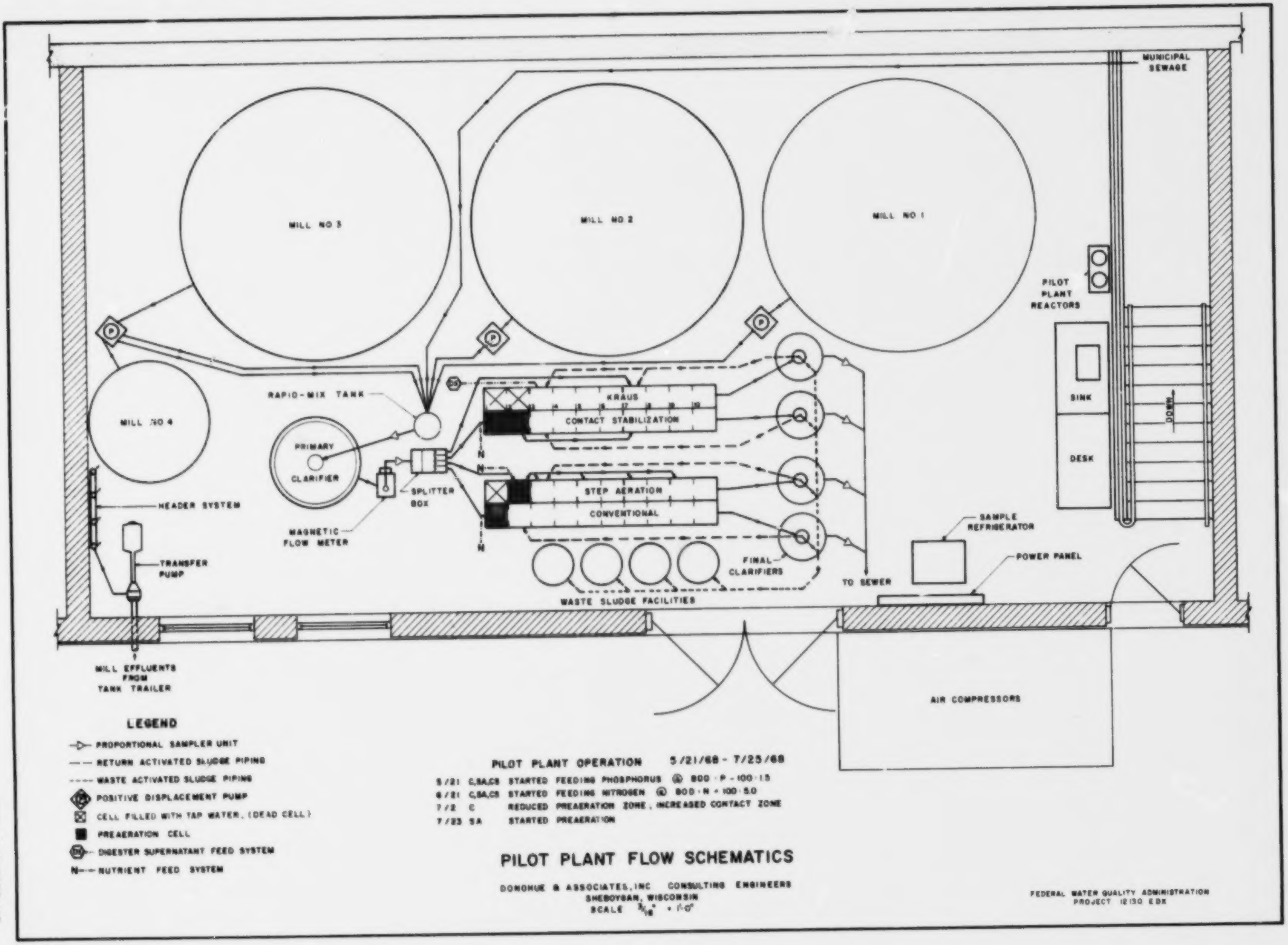
MUNICIPAL SEWAGE
MILL NO 3
MILL NO 2
MILL NO 1
MILL NO 4
PILOT PLANT REACTORS
SINK
DESK
DOWN
RAPID-MIX TANK
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
KRAUS
CONTACT STABILIZATION
STEP AERATION
CONVENTIONAL
N
FINAL CLARIFIERS
WASTE SLUDGE FACILITIES
TO SEWER
SAMPLE REFRIGERATOR
POWER PANEL
MILL EFFLUENTS FROM TANK TRAILER
AIR COMPRESSORS
LEGEND
PROPORTIONAL SAMPLER UNIT
RETURN ACTIVATED SLUDGE PIPING
WASTE ACTIVATED SLUDGE PIPING
POSITIVE DISPLACEMENT PUMP
CELL FILLED WITH TAP WATER, (DEAD CELL)
PREAERATION CELL
DIGESTER SUPERNATANT FEED SYSTEM
N NUTRIENT FEED SYSTEM
FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

PILOT PLANT OPERATION 5/21/68 - 7/23/68

5/21 C,SA,CS STARTED FEEDING PHOSPHORUS @ BOD : P - 100 : 1.5
6/21 C,SA,CS STARTED FEEDING NITROGEN @ BOD : N - 100 : 5.0
7/2 C REDUCED PREAERATION ZONE, INCREASED CONTACT ZONE
7/23 SA STARTED PREAERATION

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE $3/16"$ = 1'-0"

FIGURE 15 PAGE 115

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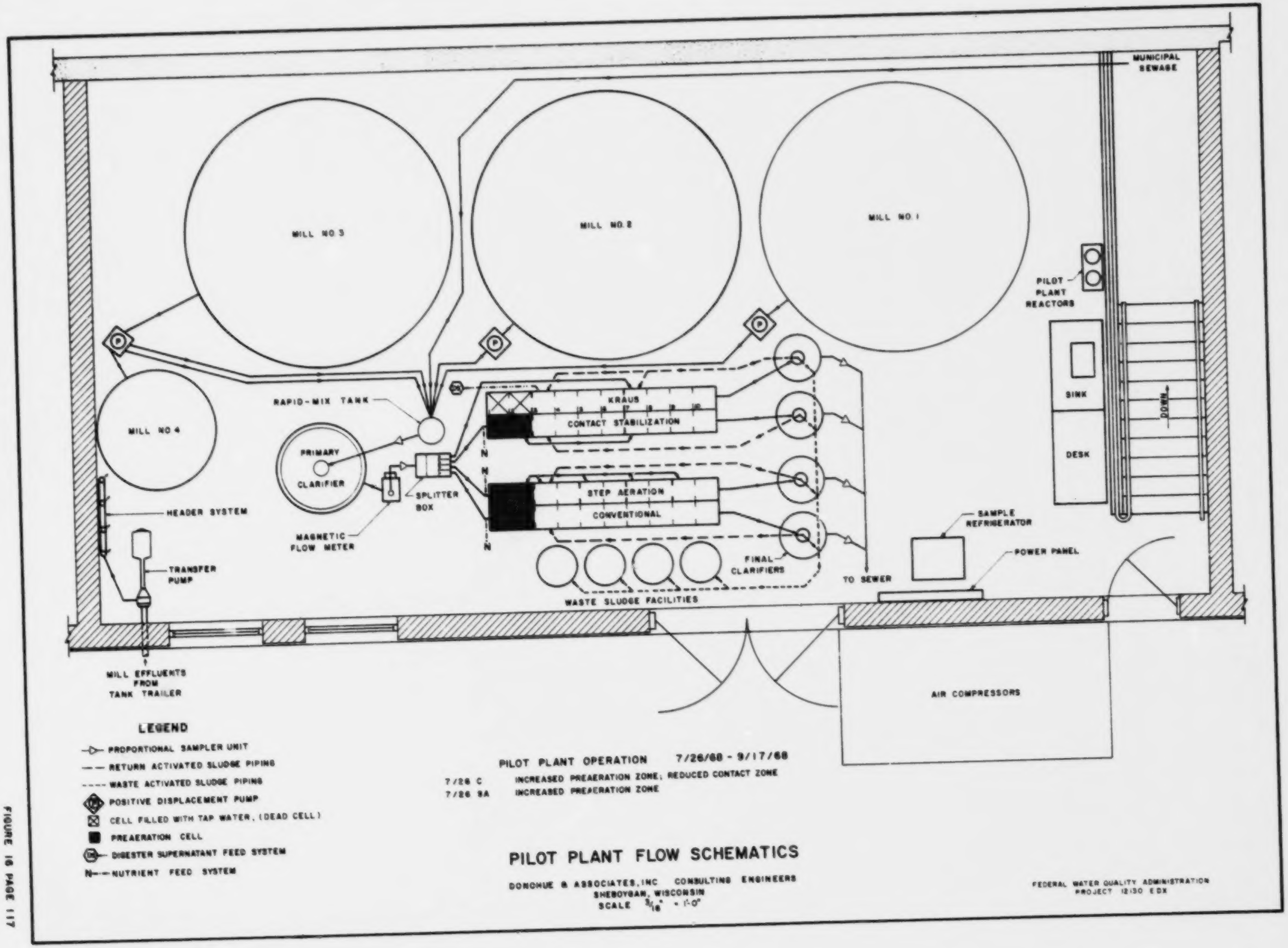
MUNICIPAL SEWAGE
MILL NO. 3
MILL NO. 2
MILL NO. 1
MILL NO. 4
PILOT PLANT REACTORS
SINK
DESK
DOWN
RAPID-MIX TANK
KRAUS
CONTACT STABILIZATION
STEP AERATION
CONVENTIONAL
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
FINAL CLARIFIERS
TO SEWER
WASTE SLUDGE FACILITIES
SAMPLE REFRIGERATOR
POWER PANEL
MILL EFFLUENTS FROM TANK TRAILER
AIR COMPRESSORS
N
LEGEND
PROPORTIONAL SAMPLER UNIT
RETURN ACTIVATED SLUDGE PIPING
WASTE ACTIVATED SLUDGE PIPING
POSITIVE DISPLACEMENT PUMP
CELL FILLED WITH TAP WATER, (DEAD CELL)
PREAERATION CELL
DIGESTER SUPERNATANT FEED SYSTEM
NUTRIENT FEED SYSTEM

PILOT PLANT OPERATION 7/26/68 - 9/17/68

7/26 C INCREASED PREAERATION ZONE; REDUCED CONTACT ZONE
7/26 9A INCREASED PREAERATION ZONE

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE 3/16" = 1'-0"

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 16 PAGE 117

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PILOT PLANT OPERATION - PHASE I

Date	Plant				Action
	C	SA	CS	K	
February 6	x	x	x	x	Startup as C units on Metro feed.
February 16	x	x	x	x	Began mill waste feed.
February 23			x		Converted C schematic to CS schematic.
February 26				x	Converted C schematic to K schematic.
March 19			x		Began preaeration of PE.
March 19				x	Split RAS flow 50-50 to nitrifying and contact sections.
March 27				x	RAS split changed to Rn-15%, Rc-85%.*
March 27				x	Digester supernatant feed started at 0.015 x Q.
April 3				x	RAS split changed to Rn-30%, Rc-70%.
April 10		x			Began step feeding at 1/4 points.
April 17	x				Began preaeration of PE; aeration section reduced to 8 cells.
April 25			x		Shock chlorination
May 2		x			Shock chlorination
May 10			x		Shock chlorination
May 24	x	x	x	x	PE-bypassing system installed to maintain F/M between 0.35 and 0.40.
May 24	x	x	x		Phosphoric acid fed to maintain BOD:Ortho P (as P) at 100:1.5 in PE.

*n - nitrification section
c - contact section

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PILOT PLANT OPERATION - PHASE I (Continued)

Date	Plant				Action
	C	SA	CS	K	
May 24	x	x	x	x	Began mathematical calculations for daily adjustment of RAS flow, WAS flow and PE-bypass flow.
June 19	x	x			Shock chlorination.
June 21		x			Shock chlorination.
June 21	x	x	x		Ammonium chloride fed to maintain BOD:NH_3 (as N) at 100:5.0 in PE.
July 1	x	x	x	x	Dissolved oxygen in aeration sections reduced to overcome denitrification in final clarifiers.
July 2	x				Reduced preaeration section to one cell.
July 12		x			Shock chlorination.
July 23		x			Began preaeration of PE.
July 26	x				Increased preaeration section to two cells.

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PILOT PLANT OPERATION - PHASE I - 3/1/68 - 8/31/68

CONVENTIONAL UNIT

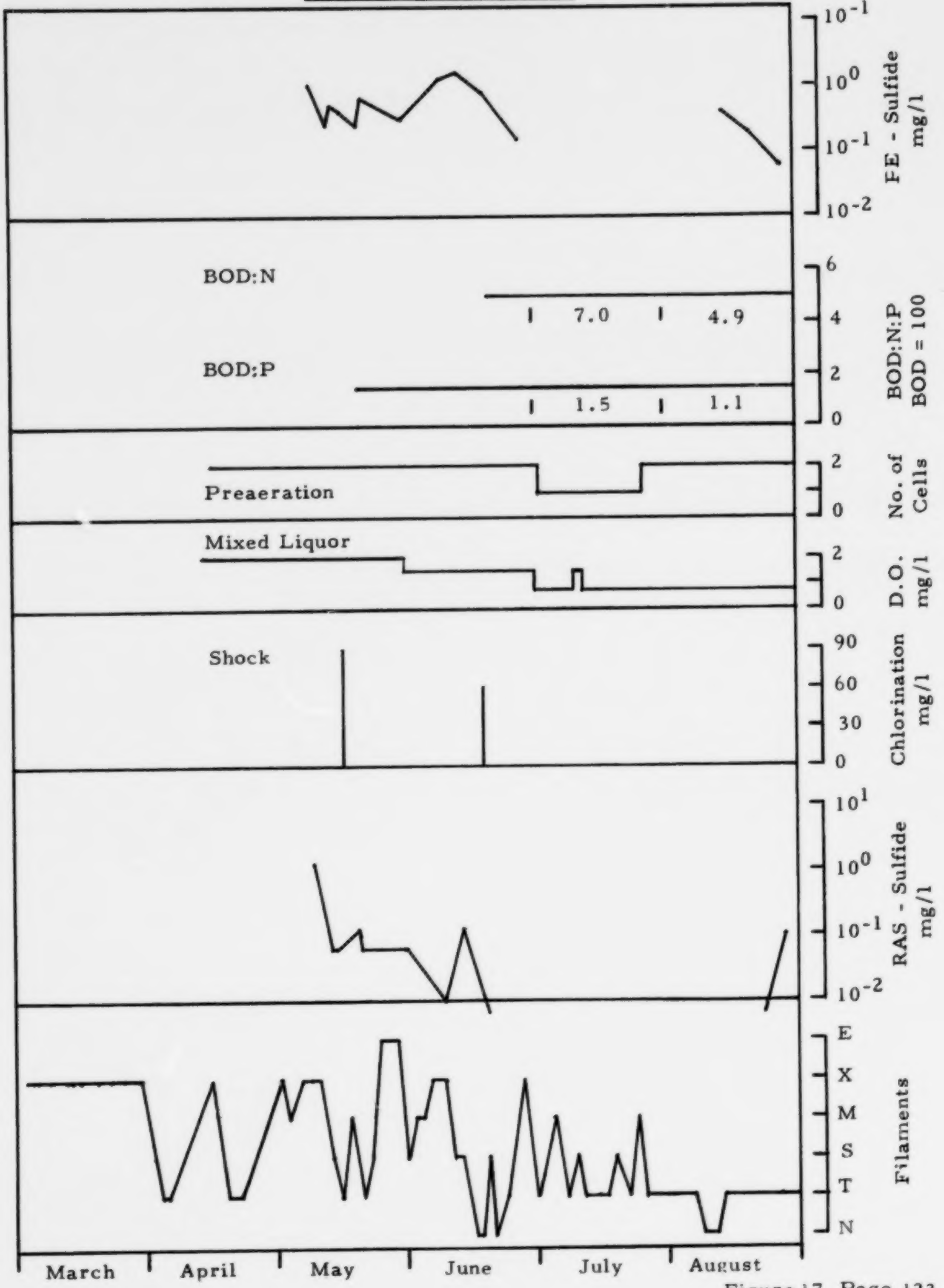

Figure 17

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PILOT PLANT OPERATION - PHASE I - 3/1/68 TO 8/31/68

STEP AERATION UNIT

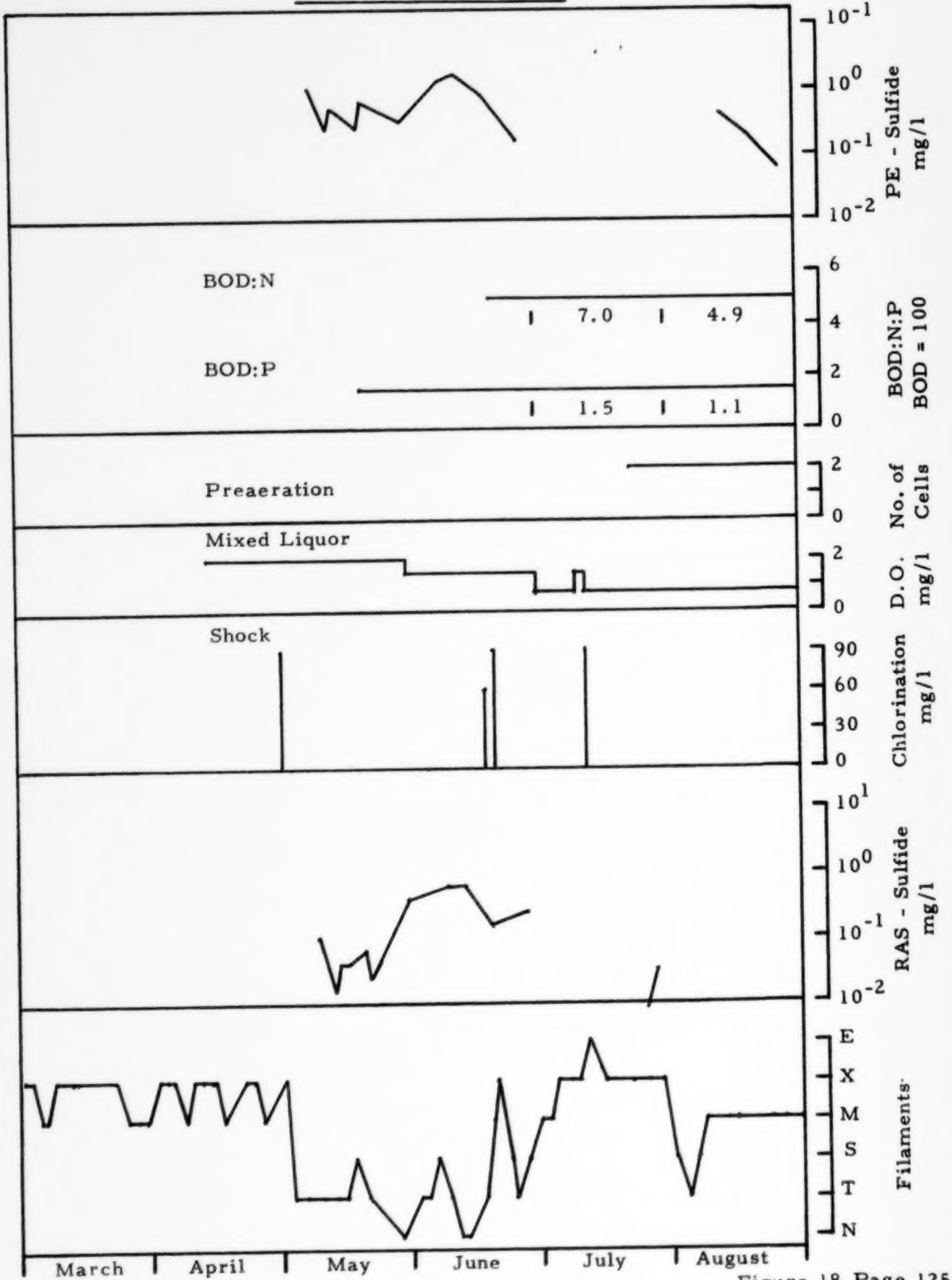

Figure 18 Page 125

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PILOT PLANT OPERATION - PHASE I - 3/1/68 TO 8/31/68

CONTACT STABILIZATION UNIT

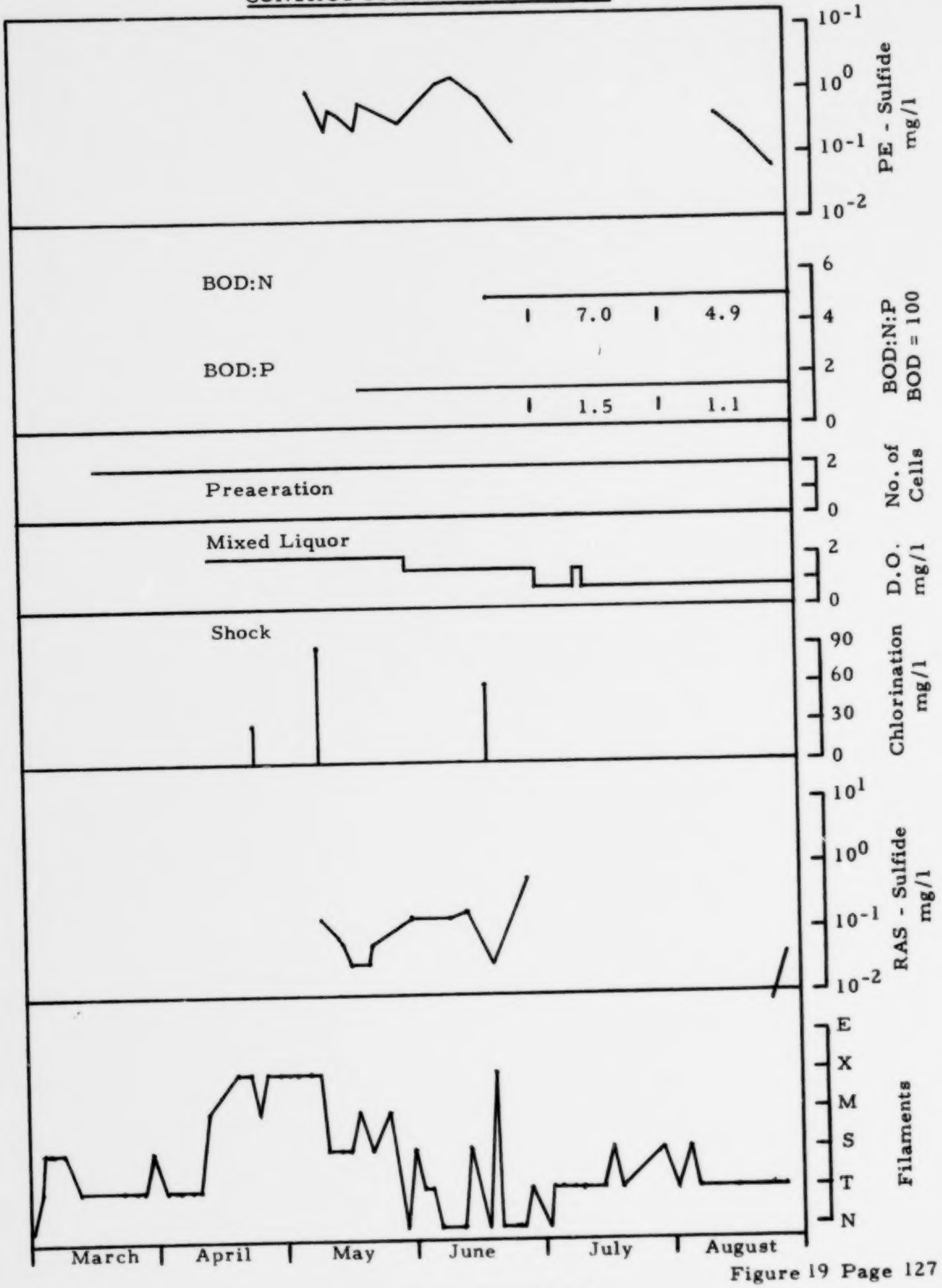

Figure 19

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PILOT PLANT OPERATION - PHASE I - 3/1/68 TO 8/31/68

KRAUS UNIT

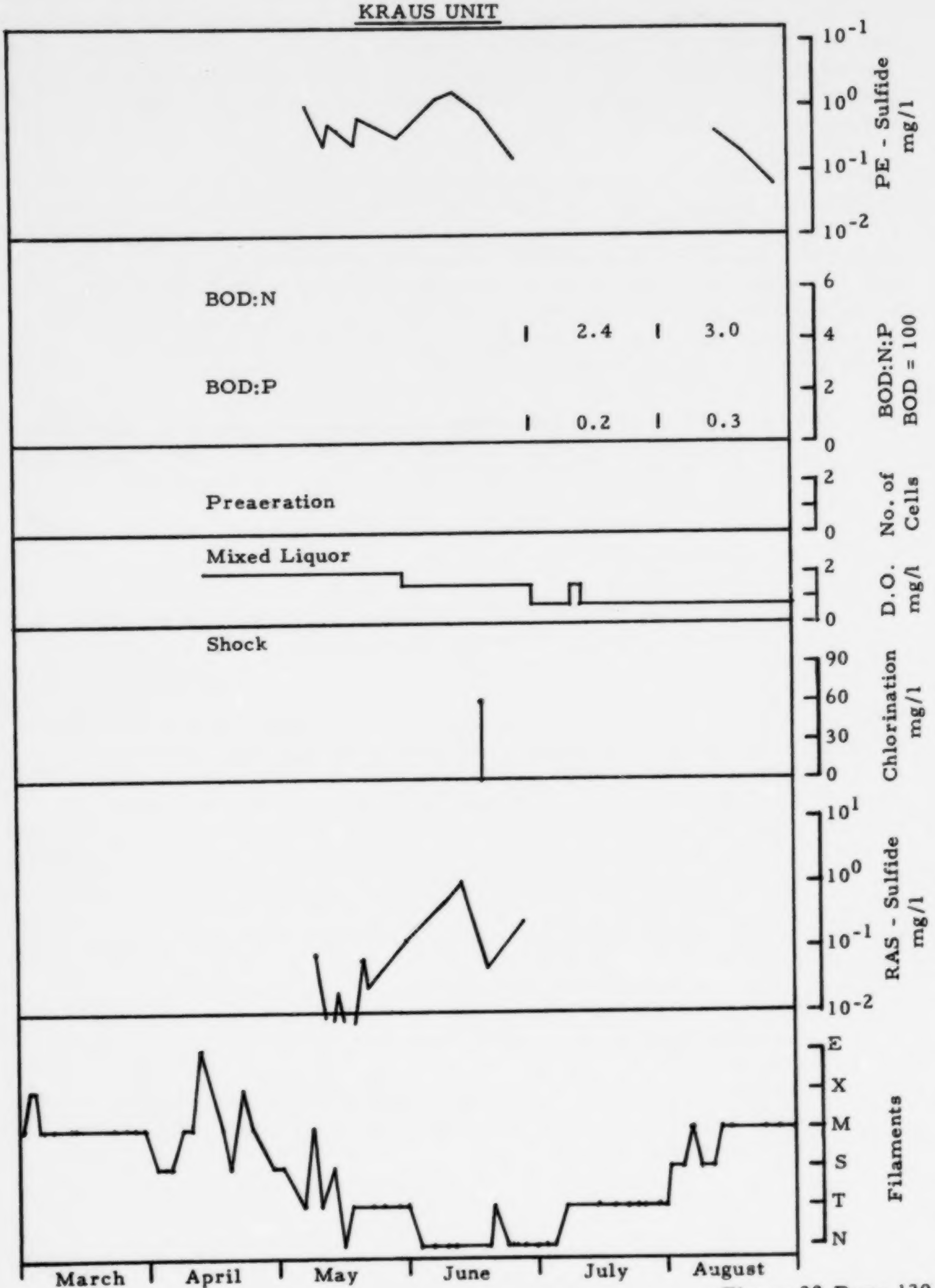

Figure 20 Page 129

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Nutrient addition was based on the concentration of BOD, ammonia (as N) and ortho phosphorus (as P) in the primary effluent. Utilizing ammonia and ortho phosphorus in the ratio, rather than total nitrogen and total phosphorus, assured that adequate nitrogen and phosphorus were available for biological growth. Ammonium chloride and phosphoric acid were added as required to maintain the desired BOD:N:P ratios.

Digester supernatant addition during Phase I and Phase II was set at 1.5% of the primary effluent flow to the Kraus unit, based upon previous operating records for the Kraus process at other locations. During Phase III, digester supernatant was used as a phosphorus source; the quantity added was controlled to obtain the desired BOD:P ratio. The ammonia nitrogen concentration in the supernatant was usually in excess of that required to maintain the desired BOD:N ratio when satisfying the phosphorus requirements.

Since the ratio of the suspended solids in primary effluent and supernatant was used in Kraus plant operational control at other locations, this ratio was calculated and presented on the data sheets during Phase III.

Shock chlorination of the aeration tank and final clarifier contents was conducted at dosages of 30 to 90 mg/l in an attempt to overcome the filamentous bulking problems. There was normally an immediate improvement in the settling characteristics of the mixed liquor after shock chlorination; however, the improvement was usually temporary. Best results were obtained at a dosage of 90 mg/l.

Changes in pilot plant operating parameters were also made in an effort to obtain satisfactory operating conditions. The operating parameters at startup are presented on Page 102. On May 24, the decision was made to limit the maximum F/M ratio to 0.375 by bypassing primary effluent. Adjustments in the concentration of volatile suspended solids in the mixed liquor were made on May 31, June 12 and July 9 to parallel the average BOD of the primary effluent.

On July 18 the following conclusions were reached on possible causes of poor operation:

1. Based upon oxygen uptake data for the conventional unit, the detention time (based upon R + Q) should be about five hours.

2. The solids loadings on the final clarifiers were high which could result in the final clarifier being a limiting unit process in the overall system.

3. The maintenance of mixed liquor volatile solids concentrations in excess of 4000 mg/l is not in accordance with present-day practice and may result in limited flexibility in the present operation.

On August 1, pilot plant operating parameters were revised as follows:

1. Average primary effluent BOD - 540 mg/l.
2. Maximum F/M ratio - 0.375.
3. Maximum total suspended solids loading on final clarifiers - 20 lbs/sq ft/day.
4. Estimated return activated sludge volatile suspended solids concentration - 9000 mg/l.
5. Maximum overflow rate on final clarifiers - 600 gpd/sq ft.
6. Maximum allowable recirculation ratio, R/Q - 0.75.
7. Average daily flow to pilot plants - 4100 liters/day; (a reduction from 1 gpm to 0.75 gpm per plant).

The new operational parameters used are presented in Table 24. The above changes resulted in an immediate and significant reduction of the sludge blanket levels in the C, CS and K processes to a level below the bottom of the final clarifier windows. The SA sludge blanket remained near mid-depth during August.

The average BOD and TSS values for Phase 1 are presented in Table 25. Based upon the performance of the units during August, which was the best overall period of operation since startup of the units, the conclusion was reached that the combination of wastes being fed to the pilot plants was biologically treatable in a continuous-flow system. Additional studies for the next phase were then outlined to attain the following objectives:

1. Obtain good reliable solids separation in the final clarifiers.
2. Conduct additional studies to estimate capital and operating costs for each process.
3. Select the most desirable process based upon costs and operational features.

PILOT PLANT OPERATIONAL PARAMETERS

August 1, 1968

Plant	No. of Cells			Mixed Liquor Volatile Suspended Solids mg/l	RAS VSS mg/l	Q l/d	Max. R/Q	F/M
	Preaeration	Reaeration	Contact					
Conventional	2		8	Cell 10 - 3860	9000	3660	0.75	0.375
Step Aeration	1		8	Cell 4 - 6750 Cell 10 - 3860	9000	4100	0.75	0.32
Contact Stabilization	1	4	4	Cell 10 - 3860	9000	4100	0.75	0.25
Kraus		4	4	Cell 10 - 3860	9000	4100	0.75	0.25

Notes

1. Due to utilizing two cells of the conventional unit for preaeration, it was necessary to bypass a portion of the flow to that plant to obtain the desired F/M ratio. Thus, the forward flow to the conventional unit was 3660 liters/day rather than 4100 liters/day.

2. N and P were added to C, SA and CS Units.

3. Digester supernatant feed to the Kraus unit = 1.5% of average Q.

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BOD AND TSS REMOVAL - PHASE I

February 6 - August 31, 1968

	mg/l		Percent Removal*	
	BOD	TSS	BOD	TSS
Primary Influent	529	237		
Primary Effluent	505	152	4.5	35.9
Final Effluent*				
Conventional	68	121	86.6	20.4
Step Aeration	89	159	82.4	0
Contact Stabilization	91	128	82.0	15.8
Kraus	96	143	81.0	5.9

* The final effluent percent removals are based on the difference between PE and FE values; the values shown are secondary treatment removal efficiencies only.

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Statistical Experimental Design

A statistical experimental design was utilized to compare the four activated sludge processes under a variety of operating conditions. The primary objective was to determine which of the four processes was best in terms of effectiveness and stability. A secondary objective was to determine the best operating conditions for the respective processes.

In choosing the independent and dependent variables for the experimental design, the relationships between operating parameters such as flow rate, mixed liquor suspended solids, F/M ratio, and detention time were investigated. The purpose was to choose two independent variables which would produce the maximum change in the response variables observed. The two independent variables selected were the mixed liquor total suspended solids concentration and the flow rate.

The question of biasing the experimental design in favor of one process arose, since preaeration or nutrient feeding was not presently a part of the Kraus process. (The digester supernatant feed to the Kraus unit was based on forward flow; however, checks on the BOD:nutrient ratios indicated there were no serious nutrient difficiencies.) The conclusion was that four individual processes were being investigated, each with its own specific operating parameters. The addition of preaeration and nutrient feeding to three of the four processes was an integral part of those particular processes in order to operate them in an acceptable manner.

The permissible range for the forward flow rate and mixed liquor total suspended solids concentration was a function of the allowable solids loading on the final clarifier and the estimated return activated sludge concentration. The average solids loading for the final clarifiers to maintain good operation was previously selected during Phase I to be about 20 lbs/sq ft/day TSS. For this experimental design a maximum loading of 30 lbs/sq ft/day at average flow was chosen to provide an operating condition of maximum stress on the units. The maximum MLTSS concentration selected was 5000 mg/l; the estimated average RAS concentration was 10,000 mg/l TSS.

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Utilizing these maximum operating values, the following five operating conditions for each plant were established:

CONDITION	I	II	III	IV	V
MLTSS, mg/l	5000	5000	3500	2000	2000
FLOW, gpm	0.8	0.4	0.6	0.4	0.8
RUN NUMBER	1	2	4, 6	3	5

Each of the above conditions was run until an apparent equilibrium of the processes was achieved for that given condition. Response data were then accumulated over a 7-day period. The schedule of operation is presented in Table 26. One condition was duplicated in order to evaluate the variability of the data obtained.

The theoretical conditions of pilot plant operation are presented in Table 27. The flow schematics utilized during the experimental design are presented in Figures 21 and 22.

The relationships between preaeration, dissolved oxygen, chlorination, nutrients, sulfides, and filamentous microorganisms during the six runs are shown in Figures 23-26.

Summary of Pilot Plant Operation During Phase II

During all phases, the mill wastes were pumped at a continuous rate to the pilot plant units. Beginning September 16, 1968, and continuing through Phases II, III, and IV, the Metro sewage pumped to the pilot plants was varied proportionately to the flow through the existing GBMSD full-scale treatment plant. (Refer to the section entitled Pilot Plant Operation.)

The average primary effluent BODs for Runs 1-6, respectively, were 469, 530, 609, 522, 667 and 372 mg/l. During Phase II and III the average quantities of ammonia and ortho phosphorus contributed by the digester supernatant to the Kraus unit were included in the BOD:N:P ratio calculations.

STATISTICAL EXPERIMENTAL DESIGN SCHEDULE -- 1968-1969

Run	Operating Condition	Acclimation	Data Collection	Total Length of Run, Days
1	I	September 9 -- October 7	October 8 -----October 14	36
2	II	October 15 ---- October 25	October 26 ----November 1	18
3	IV	November 2 --- November 14	November 15 --November 21	20
4	III	November 22 -- December 4	December 5 ---December 11	20
5	V	December 12 --December 28	December 29 --January 4	24
6	III	January 5 -----January 24	January 25 ----January 31	27

THEORETICAL PILOT PLANT OPERATION - PHASE II

	Q	R	R/Q	Dig.* Sup.	Detention Time, Hours						MLTSS	F/M (BOD/VSS)				Final Clarifier Solids Loading
					Contact R + Q + Dig. Sup.				Reaeration R+Dig. Sup.							
	gpm	gpm		gpm	C	SA	CS	K	CS	K	mg/l	C	SA	CS	K	Lbs/Sq ft/day
I	0.80	0.80	1.00	0.012	3.8	3.8	1.9	1.9	3.8	11.9	5000	0.38	0.30	0.26	0.27	30.6
II	0.40	0.40	1.00	0.006	7.5	7.5	3.8	3.7	7.5	23.8	5000	0.19	0.15	0.13	0.14	15.3
III	0.60	0.32	0.54	0.009	6.5	6.5	3.3	3.2	9.3	28.3	3500	0.41	0.29	0.21	0.23	12.4**
IV	0.40	0.10	0.25	0.006	12.0	12.0	6.0	5.9	30.0	84.0	2000	0.48	0.30	0.16	0.17	3.8**
V	0.80	0.20	0.25	0.012	6.0	6.0	3.0	3.0	15.0	41.7	2000	0.96	0.60	0.32	0.34	7.6**

* Kraus unit only.

** Kraus values for these conditions are 12.5, 3.9 and 7.7 Lbs/Sq ft/day respectively.

Note:

1. MLVSS estimated at 90% of MLTSS for C, SA and CS units and at 85% for K unit.

2. RAS-TSS estimated at 10,000 mg/l.

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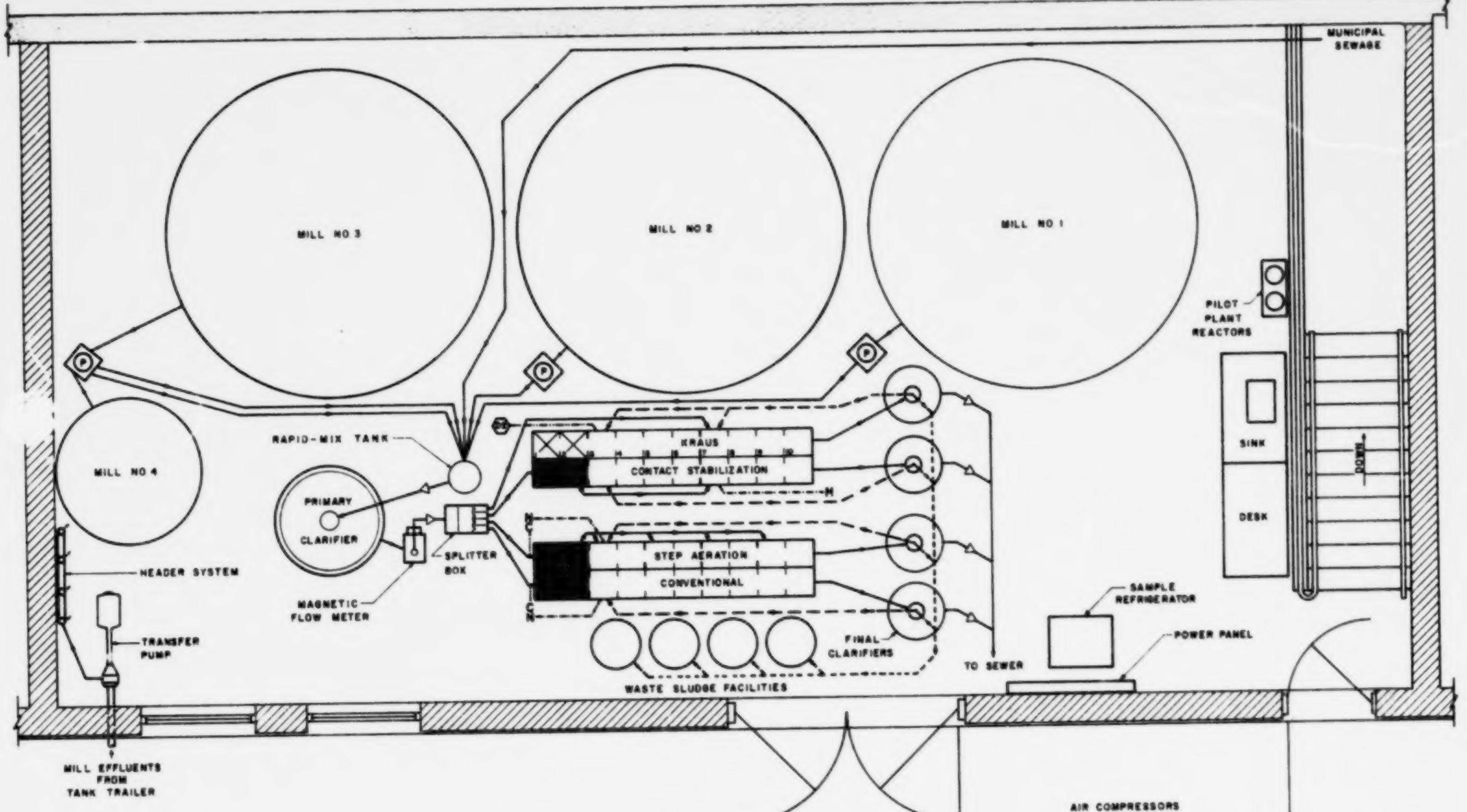
MUNICIPAL SEWAGE
MILL NO 3
MILL NO 2
MILL NO 1
PILOT PLANT REACTORS
SINK
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RAPID-MIX TANK
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SAMPLE REFRIGERATOR
POWER PANEL
MILL EFFLUENTS FROM TANK TRAILER
AIR COMPRESSORS
N
C

LEGEND

-▷- PROPORTIONAL SAMPLER UNIT

— — RETURN ACTIVATED SLUDGE PIPING

- - - - WASTE ACTIVATED SLUDGE PIPING

◆ POSITIVE DISPLACEMENT PUMP

☒ CELL FILLED WITH TAP WATER, (DEAD CELL)

■ PREAERATION CELL

⬡- DIGESTER SUPERNATANT FEED SYSTEM

N— —NUTRIENT FEED SYSTEM

C······CHLORINE FEED SYSTEM

PILOT PLANT OPERATION 9/18/68 - 1/14/69

9/18 C,SA,CS CHANGED NUTRIENT FEED POINT TO CONTACT ZONE
10/1 C,SA STARTED PRECHLORINATION

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE $3/16'' = 1'\text{-}0''$

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 21 PAGE 143

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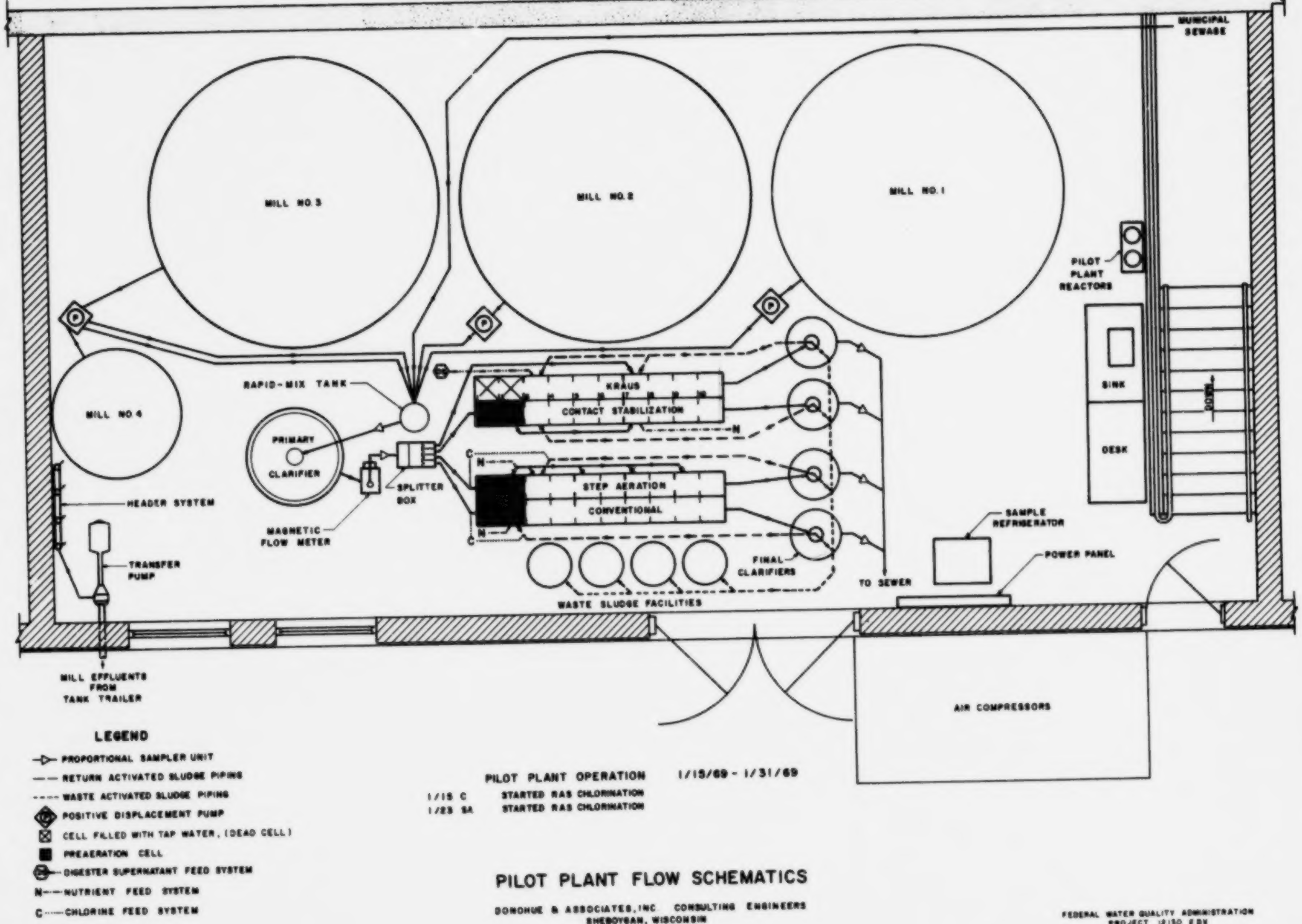
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PILOT PLANT REACTORS
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C
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POWER PANEL
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MILL EFFLUENTS FROM TANK TRAILER
LEGEND
PROPORTIONAL SAMPLER UNIT
RETURN ACTIVATED SLUDGE PIPING
WASTE ACTIVATED SLUDGE PIPING
POSITIVE DISPLACEMENT PUMP
CELL FILLED WITH TAP WATER, (DEAD CELL)
PREAERATION CELL
DIGESTER SUPERNATANT FEED SYSTEM
N—NUTRIENT FEED SYSTEM
C—CHLORINE FEED SYSTEM

PILOT PLANT OPERATION 1/15/69 - 1/31/69

1/15 C STARTED RAS CHLORINATION
1/23 SA STARTED RAS CHLORINATION

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE $\frac{3}{16}'' = 1'\text{-}0''$

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 22 PAGE 145

PILOT PLANT OPERATION - PHASE II - 9/1/68 TO 1/31/69

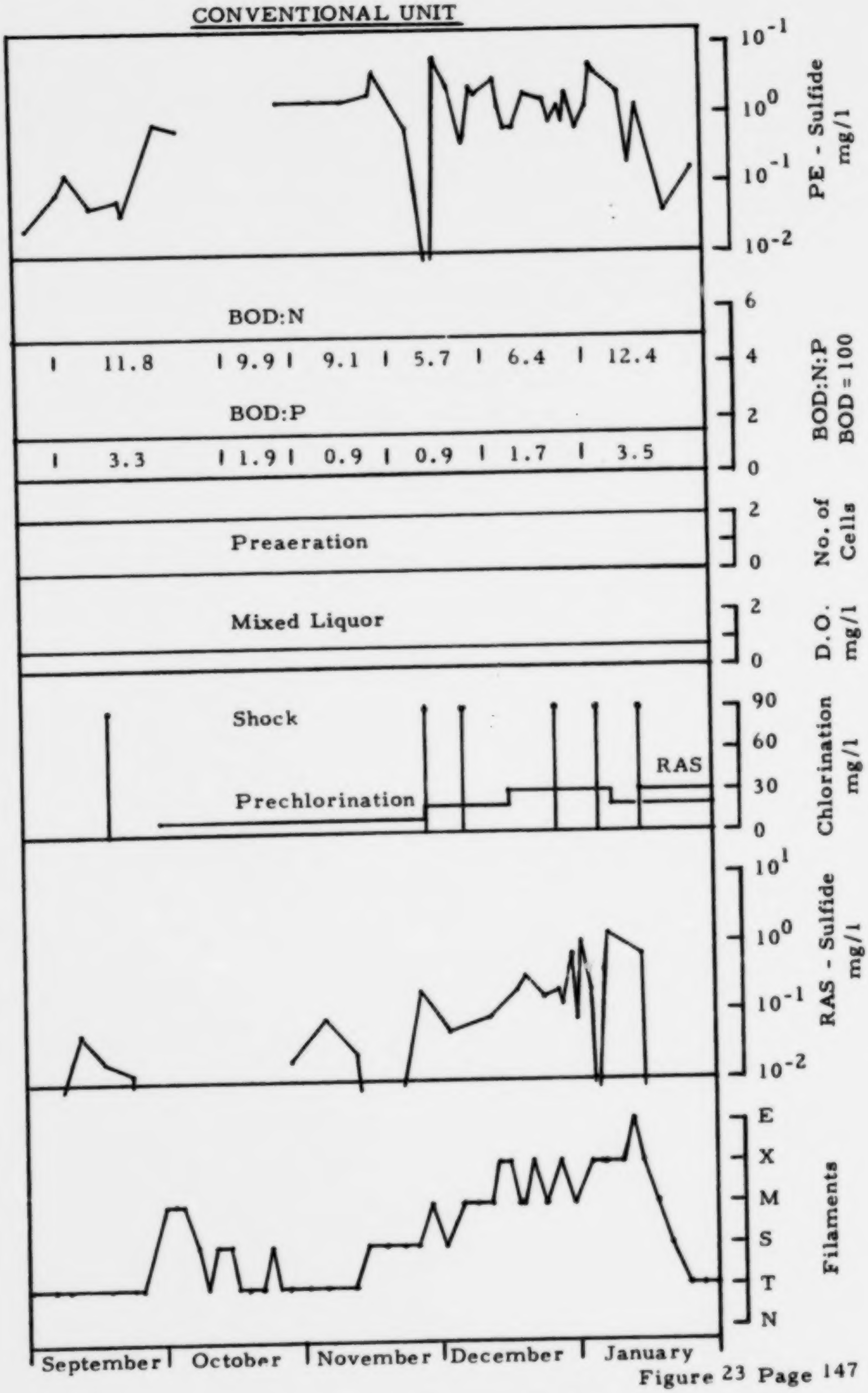

Figure 23

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PILOT PLANT OPERATION - PHASE II - 9/1/68 TO 1/31/69

STEP AERATION UNIT

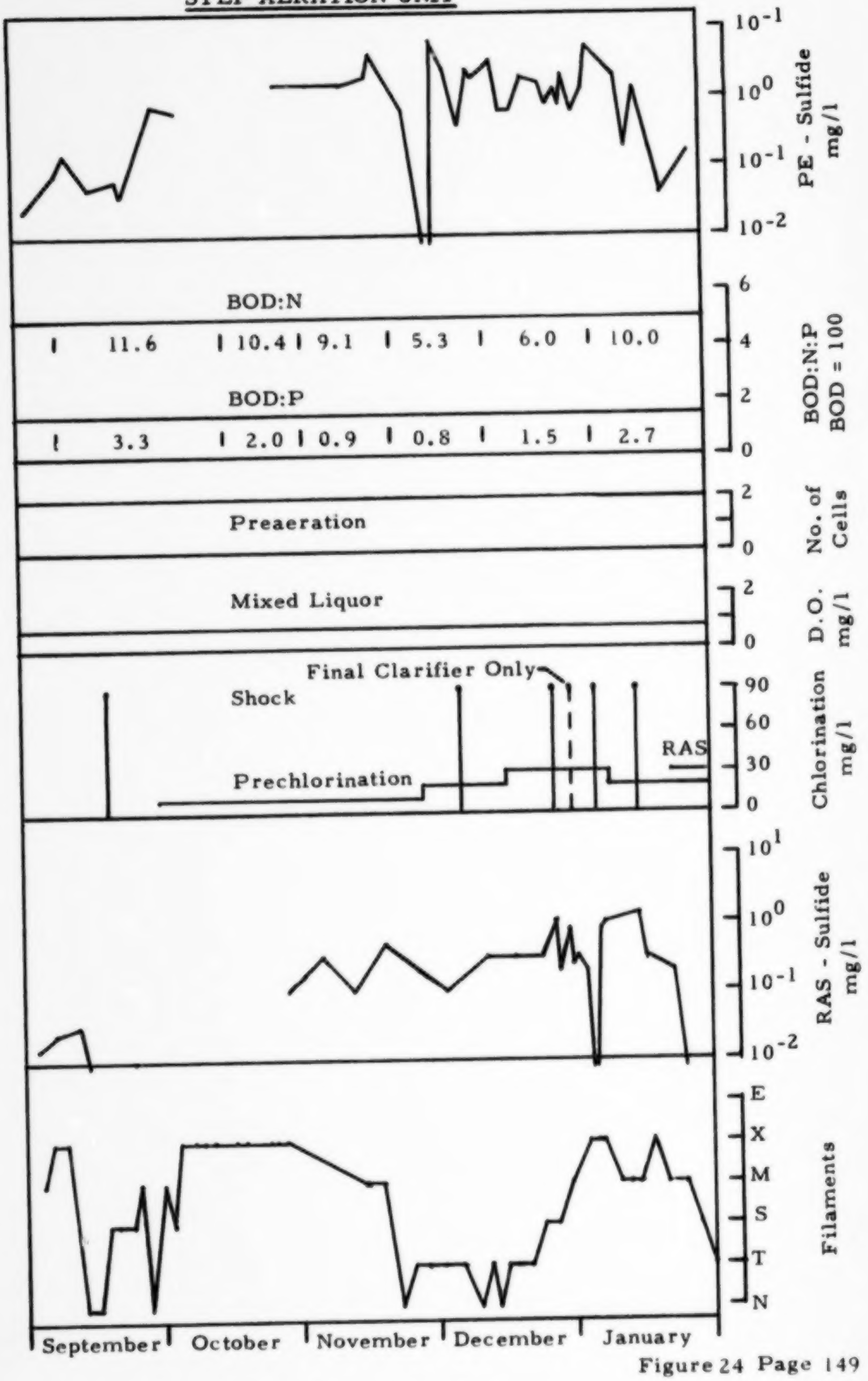

Figure 24

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PILOT PLANT OPERATION - PHASE II - 9/1/68 TO 1/31/69

CONTACT STABILIZATION UNIT

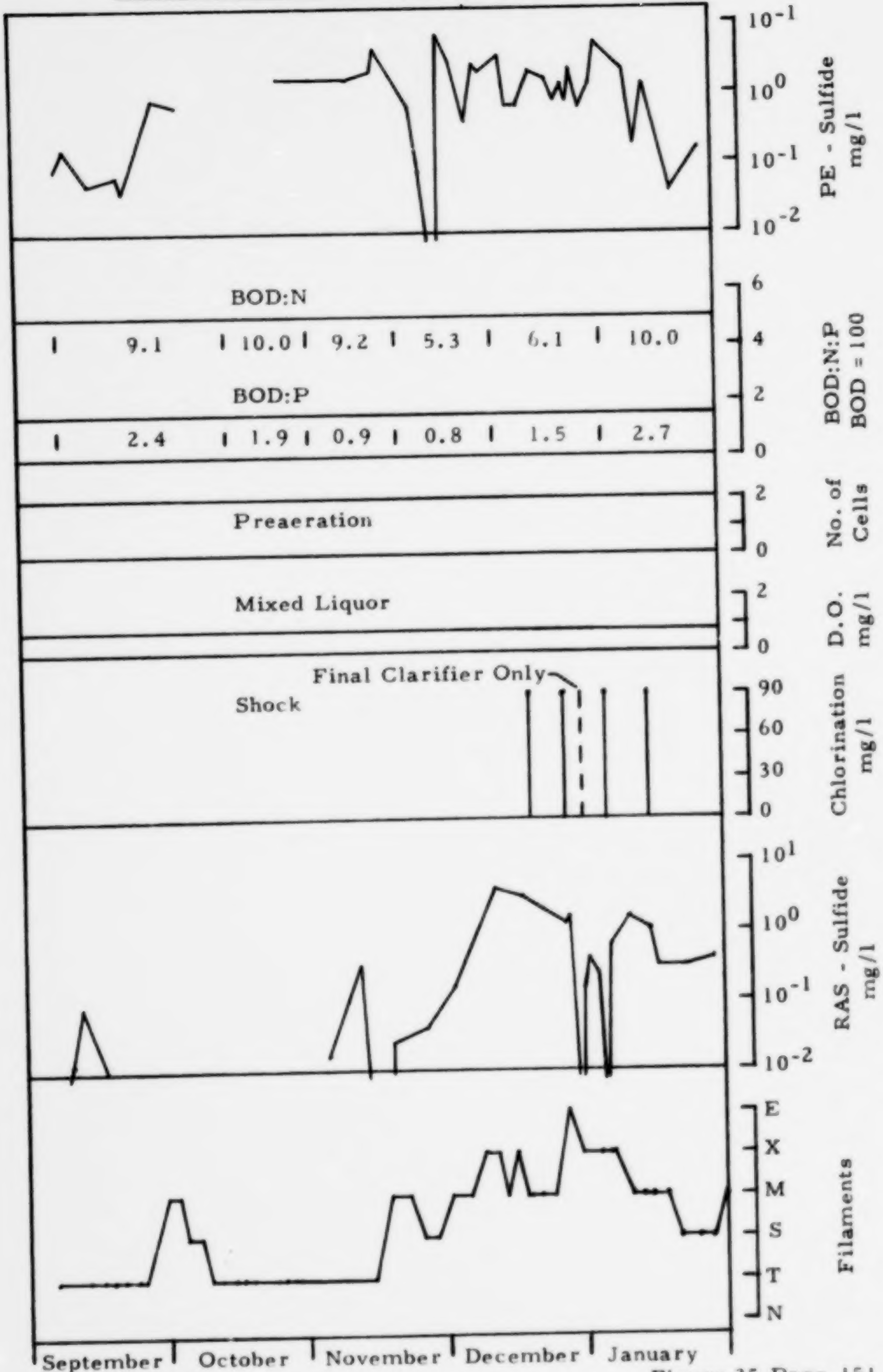

Figure 25 Page 151

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PILOT PLANT OPERATION - PHASE II - 9/1/68 TO 1/31/69

KRAUS UNIT

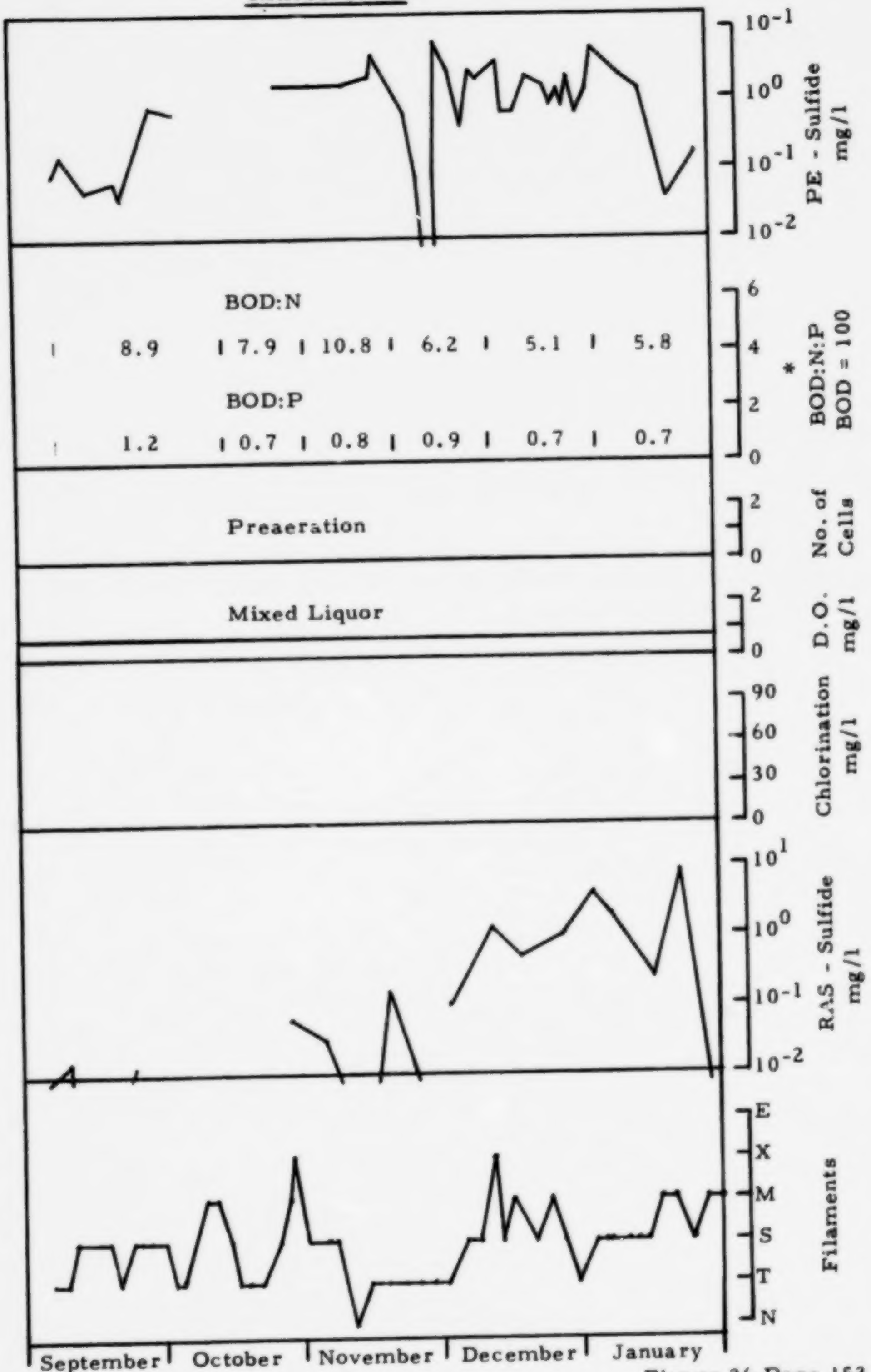

Figure 26 Page 153

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Operational Summary

Run 1, Condition I

CS - Best physical operation of the four plants.

CS and K - Decrease in treatment efficiency compared to August; process more stable than C and SA.

K - Good-settling mixed liquor; higher TSS and BOD in effluent than CS.

C and SA - Did not achieve desired MLTSS concentration.

SA - Higher TSS and BOD in effluent than C.

Run 2, Condition II

CS - Best overall performance, followed by C.

SA - Least-stable process; did not achieve desired MLTSS; RAS concentration did not exceed 9000 mg/l; final clarifier sludge blanket rose to weir level.

K - Quite stable, but higher TSS and BOD in final effluent than C and CS.

Run 3, Condition IV

C - Best operation of four plants.

C, CS - Clear effluent.

SA, K - Cloudy effluent.

SA, CS, K -Erratic RAS concentration; difficult to maintain correct MLTSS in K unit.

Four plants generally operated well during this Run; no apparent problems due to filamentous microorganisms.

Run 4, Condition III

K - Superior performance, followed in order by CS, C and SA.

C, SA - Did not achieve desired MLTSS concentration; had high TSS and BOD in final effluent; RAS-TSS less than 5000 mg/l.

Filaments - C-moderate; SA-slight; CS-excessive; K-slight.

Run 5, Condition V

During this run the pilot plants were subjected to the most overloaded operating conditions of the experimental design. As a result, filamentous growths occurred in the C, SA and CS plants causing severe bulking conditions and subsequent loss of biological solids in the final effluent. The K unit, although containing filaments and exhibiting poor effluent quality, did not have any filamentous bulking problems.

Run 6, Condition III

The purpose of this Run was to repeat the operating condition of Run 4, Condition III. As this Run followed Run 5, Condition V, which was a highly-overloaded operating condition, the plants required a period of time to recover and begin operating at the desired conditions for Run 6.

On January 5, the C, SA and CS plants were shock chlorinated; bypassing of the feed to the C, SA and CS plants between January 5 and January 25 was also conducted to reduce the F/M values to a level to allow the plants to regain good operation. On January 14, the C, SA and CS plants were again shock chlorinated in an effort to eliminate the bulking conditions.

On January 5, there were excessive filaments in the C, SA and CS plants which appeared to be of the _Sphaerotilus natans_ variety; (no sulfur granules were observed). About January 11, a biological change took place in that a _Thiothrix_ variety appeared to become the more dominant filament present. The amount of filaments in the four pilot plants was slight to moderate during the seven-day period of tests, January 25 to January 31. The microbiology report stated that the biological conditions were as good as had been observed for some time.

Chlorination of the return activated sludge at 30 mg/l for the C and SA units was begun January 15 and 23, respectively. An immediate increase in RAS concentration resulted.

In summary, the pilot plants operated as well during Run 6 as any time during the experimental design. This can probably be attributed to the lower primary effluent BOD and also to the chlorination of the return activated sludge for the C and SA units.

Statistical Experimental Design - Laboratory Data

Data were obtained for 13 response variables during the last seven days of each run. The response variables in order of importance were:

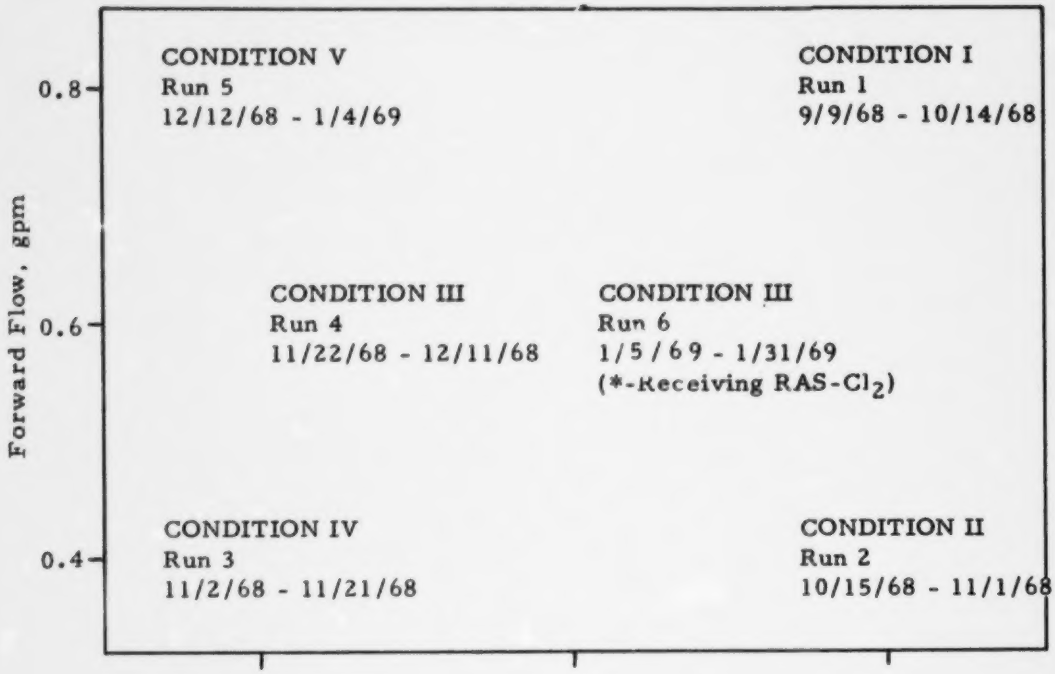
1.	Final effluent filtered BOD	(7)
2.	Final effluent total suspended solids	(7)
3.	Final clarification	(1)
4.	Filament concentration	(2-3)
5.	Pounds oxygen required/pound BOD removed	(1)
6.	Return activated sludge concentration	(7)
7.	Sludge production	(7)
8.	Specific filtration resistance of WAS	(1)
9.	Air flotation of mixed liquor and WAS	(1)
10.	Final effluent filterability index	(1-3)
11.	Final effluent unfiltered BOD	(7)
12.	Final clarifier sludge level	(7)
13.	Final effluent color	(2-3)

The numbers in parentheses are the number of tests averaged to obtain the values for each plant for each run.

The summary of data obtained for each of these 13 responses is presented in Figures 27 to 34. Figure 27 shows the operating conditions and respective run numbers located according to the mixed liquor total suspended solids and forward flow for that particular run. Figure 34 shows the MLTSS concentration and the detention time in the contact and reaeration section which actually occurred during each run. The following comments apply to these Figures:

1. The data shown are the average of the values obtained during the last seven days of each run. (Where appropriate, data columns are identified in the lower right hand corner of the Figures.)
2. Standard deviations were computed for several of the response variables and are listed under the abbreviation, S.D.
3. Final effluent filtered BOD's were run on samples filtered through Whatman No. 5 filter paper.
4. The abbreviations C.R. and T_c for the response variable, final clarification, refer to the clarification rate (gpd/sf) and time of concentration (minutes) to obtain a 1% underflow concentration.
5. The sludge production data are based upon both unfiltered BOD's (PE and FE BOD values) and filtered BOD's (filtered PE and filtered FE BOD values).
6. SFR = specific filtration resistance
7. The color data are as standard units, based upon a platinum cobalt standard.
8. The procedures for the final clarification studies, air flotation studies and sludge production calculations are presented in Appendix B. All other test procedures utilized in the experimental design are presented in the section entitled Laboratory Staff, Equipment, Procedures and Data Reduction.
9. During Run 6, Condition 3 (1/5/69-1/31/69) the C and SA units began receiving RAS chlorination as indicated by an asterisk.

STATISTICAL EXPERIMENTAL DESIGN SCHEDULE


Forward Flow, gpm
0.8
0.6
0.4
CONDITION V
Run 5
12/12/68 - 1/4/69
CONDITION I
Run 1
9/9/68 - 10/14/68
CONDITION III
Run 4
11/22/68 - 12/11/68
CONDITION III
Run 6
1/5/69 - 1/31/69
(*-Receiving RAS-Cl2)
CONDITION IV
Run 3
11/2/68 - 11/21/68
CONDITION II
Run 2
10/15/68 - 11/1/68

FINAL EFFLUENT FILTERED BOD, (mg/l)

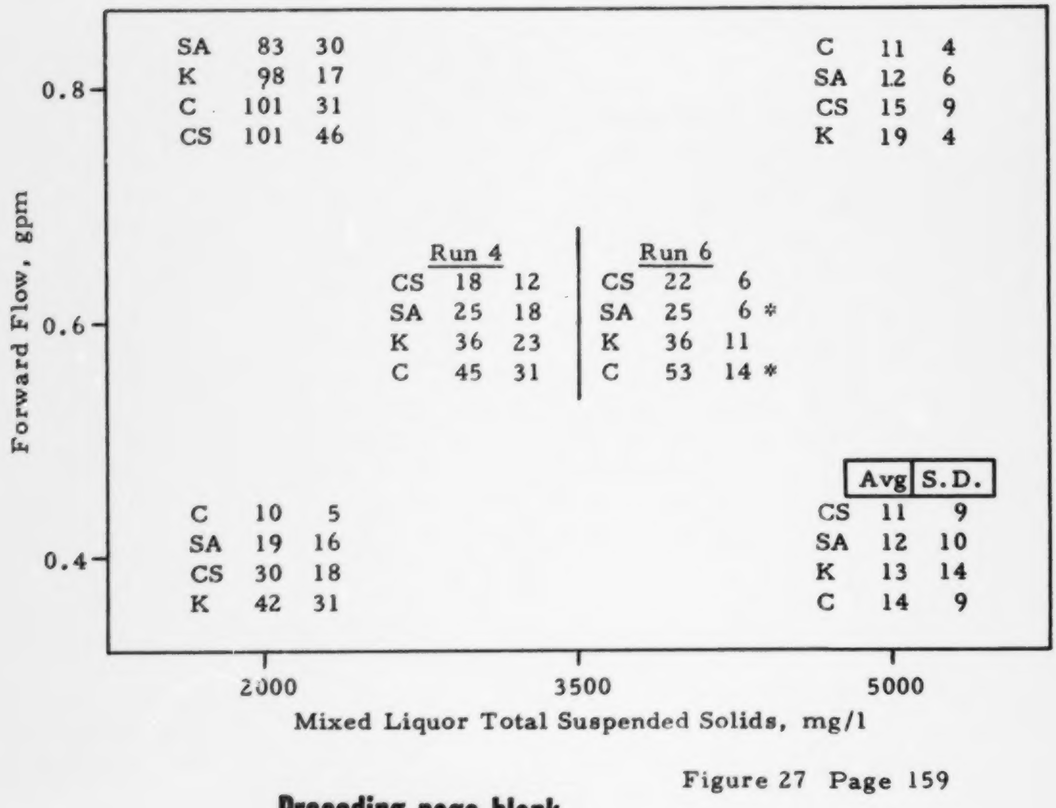


Figure 27 Page 159

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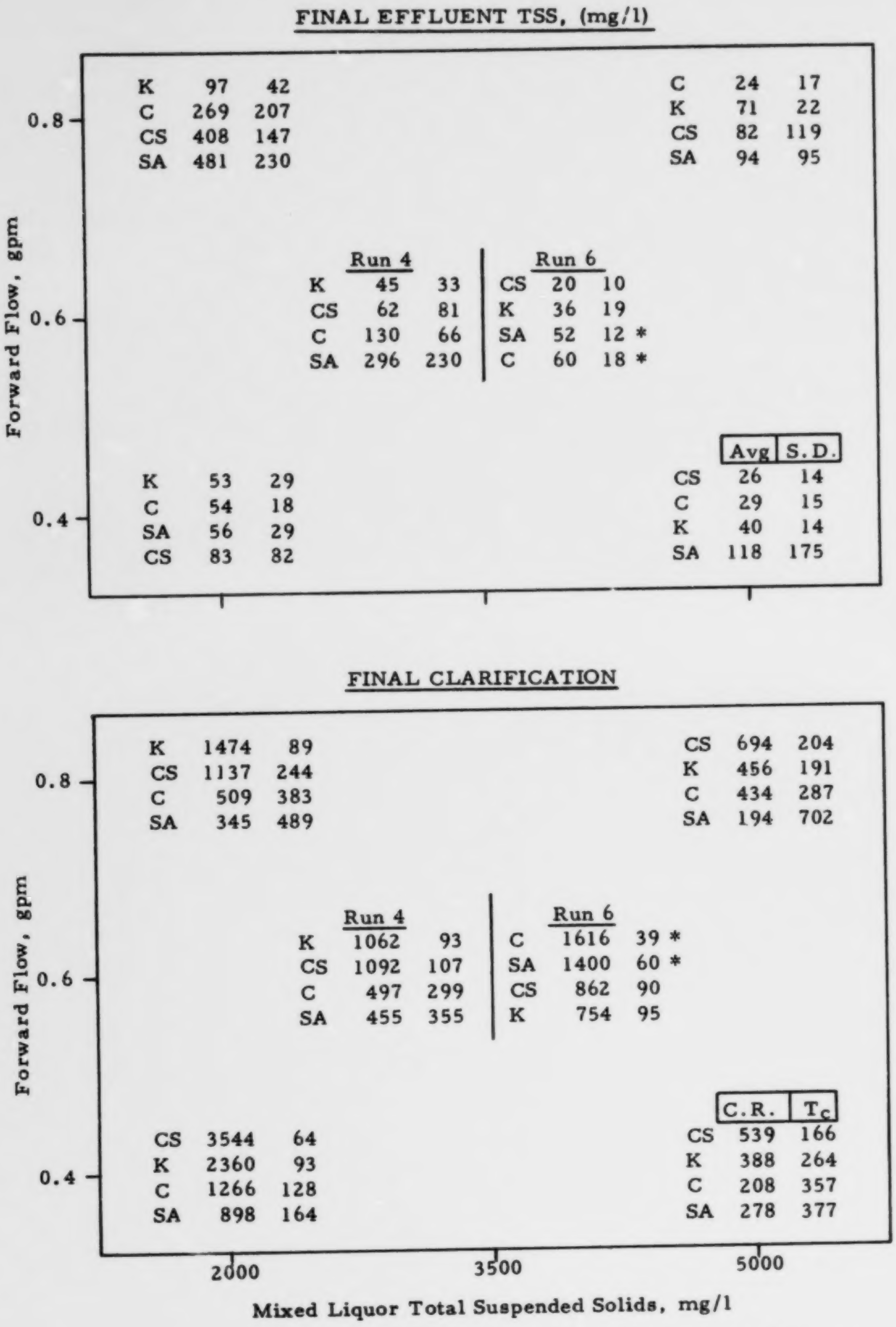

Figure 28 Page 161

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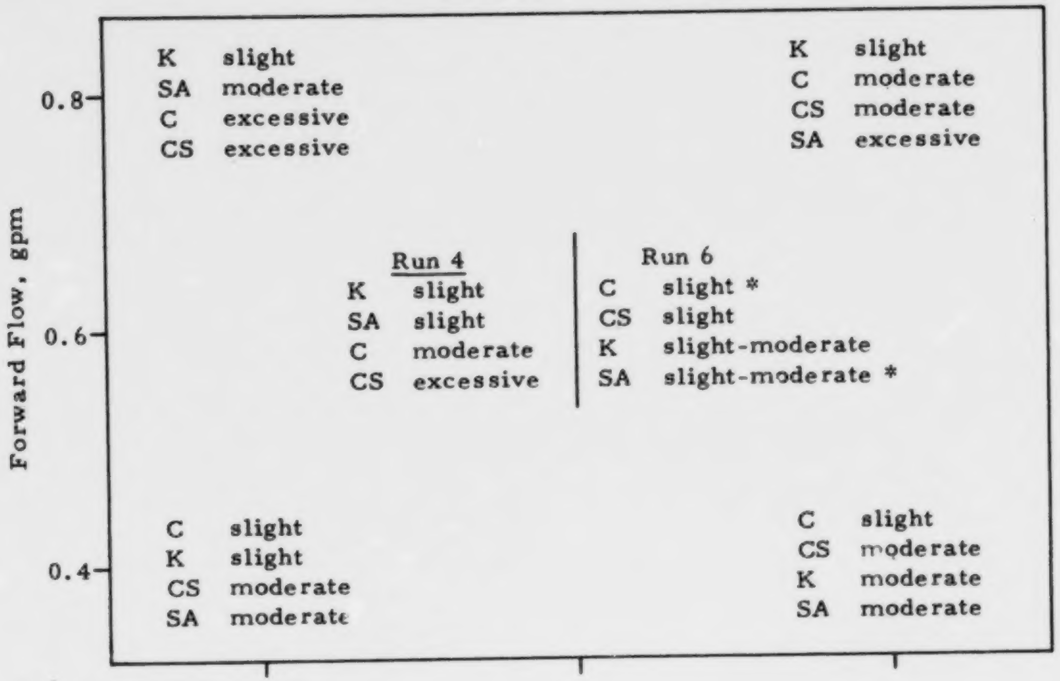
FILAMENT CONCENTRATION



Lbs. OXYGEN REQUIRED / Lb. BOD REMOVED

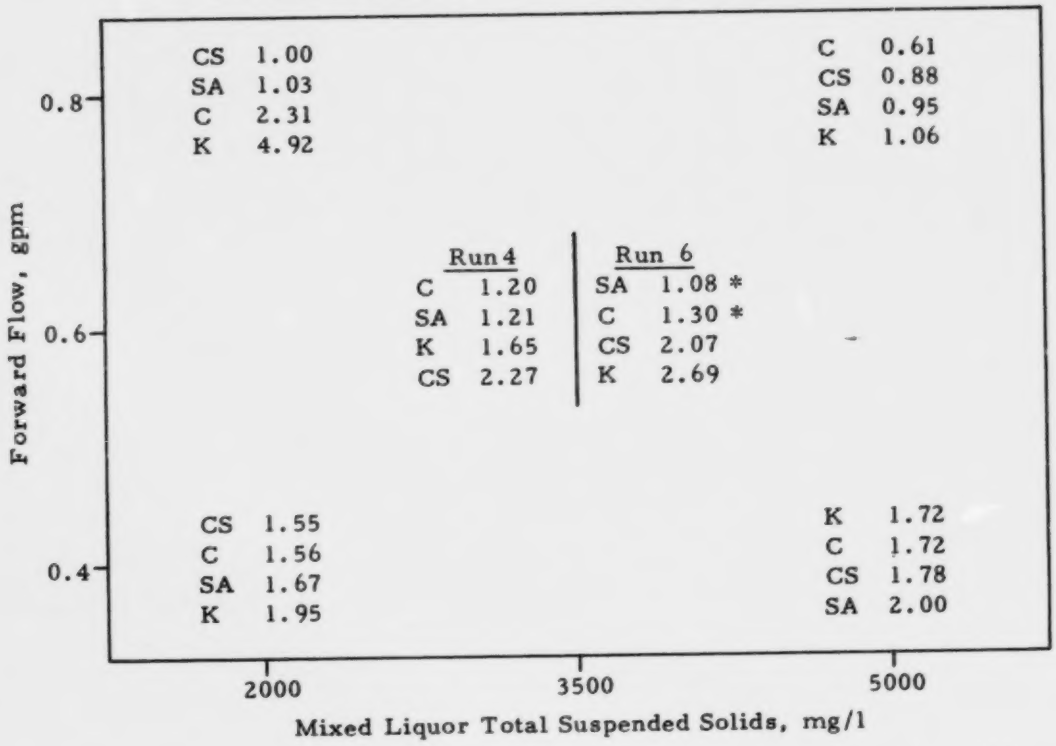


Figure 29 Page 163

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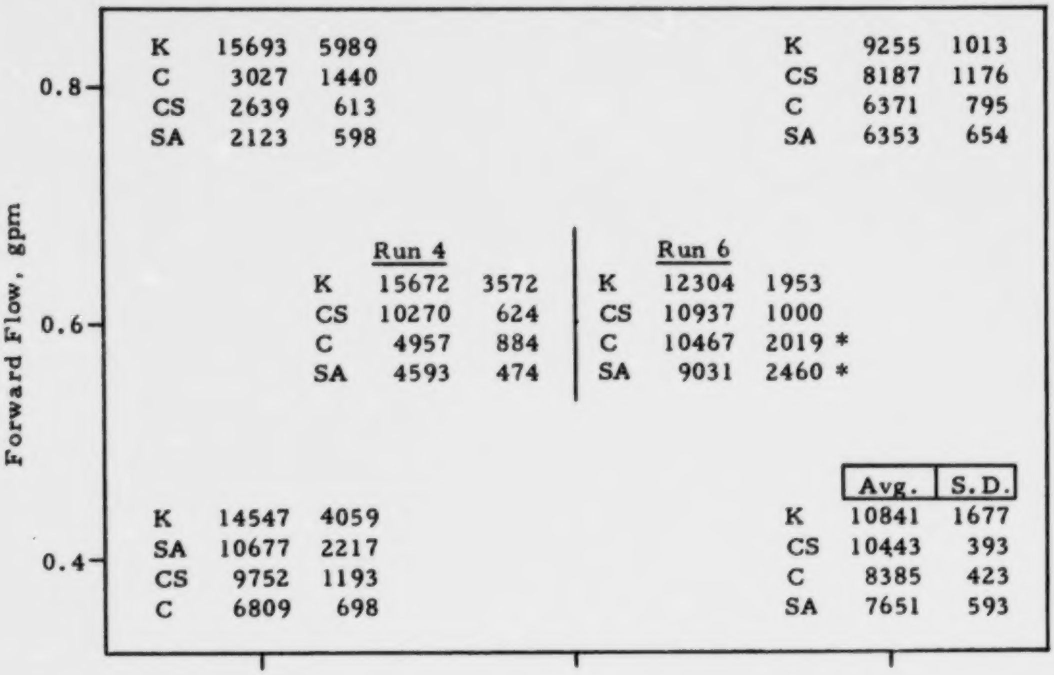
RAS CONCENTRATION, (TSS, mg/l)



SLUDGE PRODUCTION, (Lbs. TSS Produced/Lb. BOD Removed)

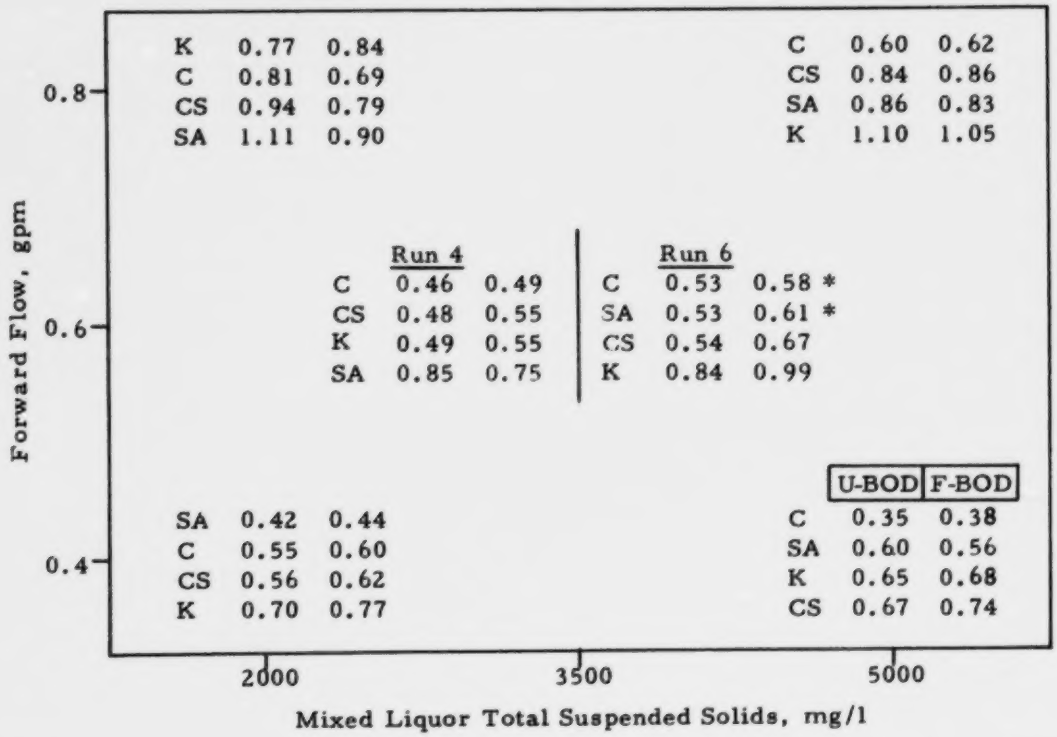


Figure 30 Page 165

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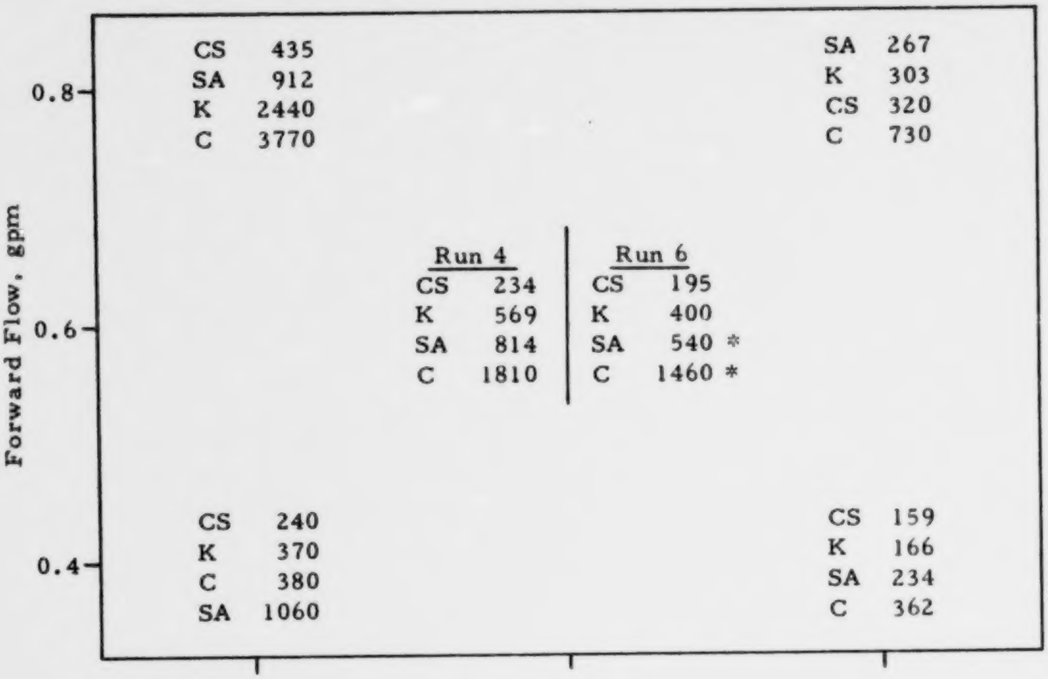
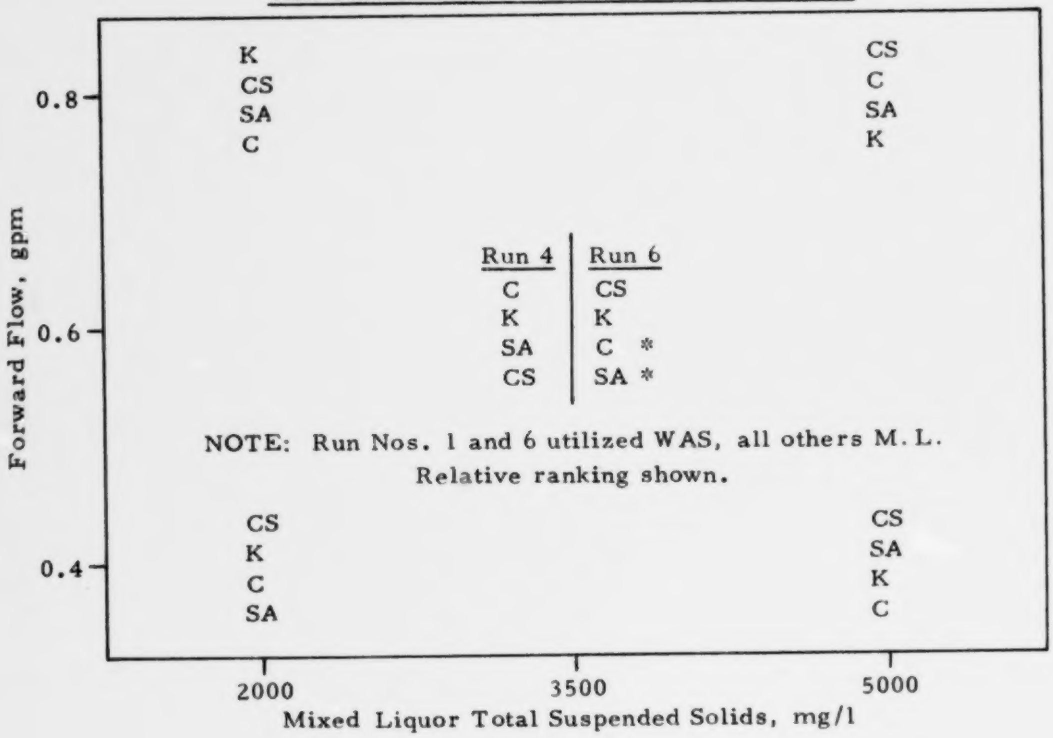


SFR - WASTE ACTIVATED SLUDGE, (x 10^7 sec^2/grams)



AIR FLOTATION of WAS & MIXED LIQUOR

NOTE: Run Nos. 1 and 6 utilized WAS, all others M. L.
Relative ranking shown.

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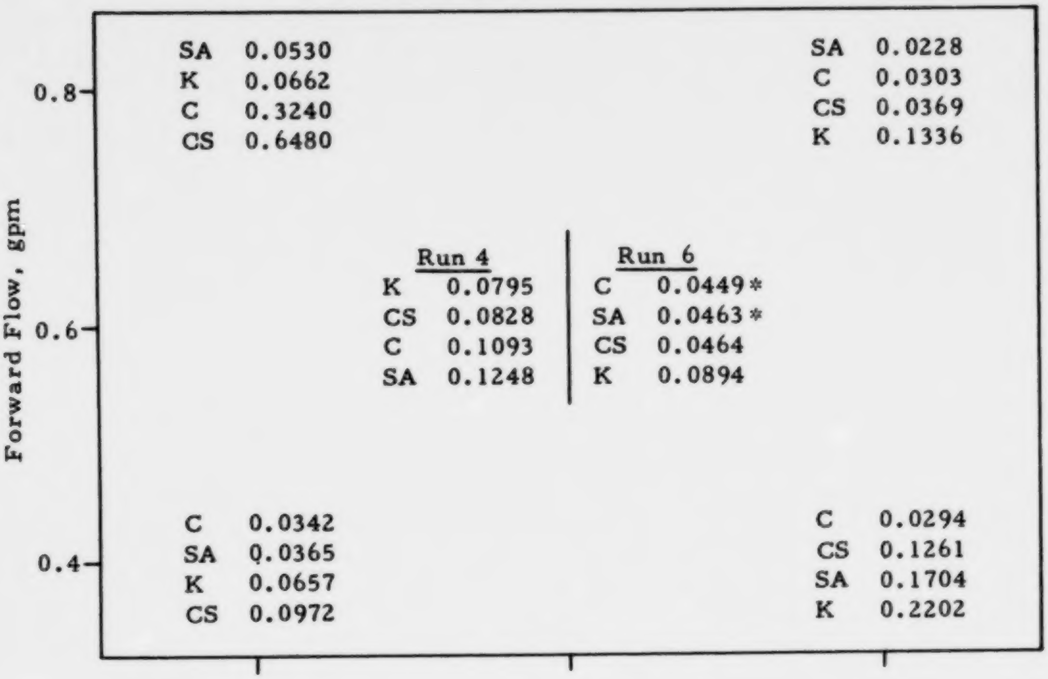
FINAL EFFLUENT FILTERABILITY INDEX



FINAL EFFLUENT UNFILTERED BOD, (mg/l)

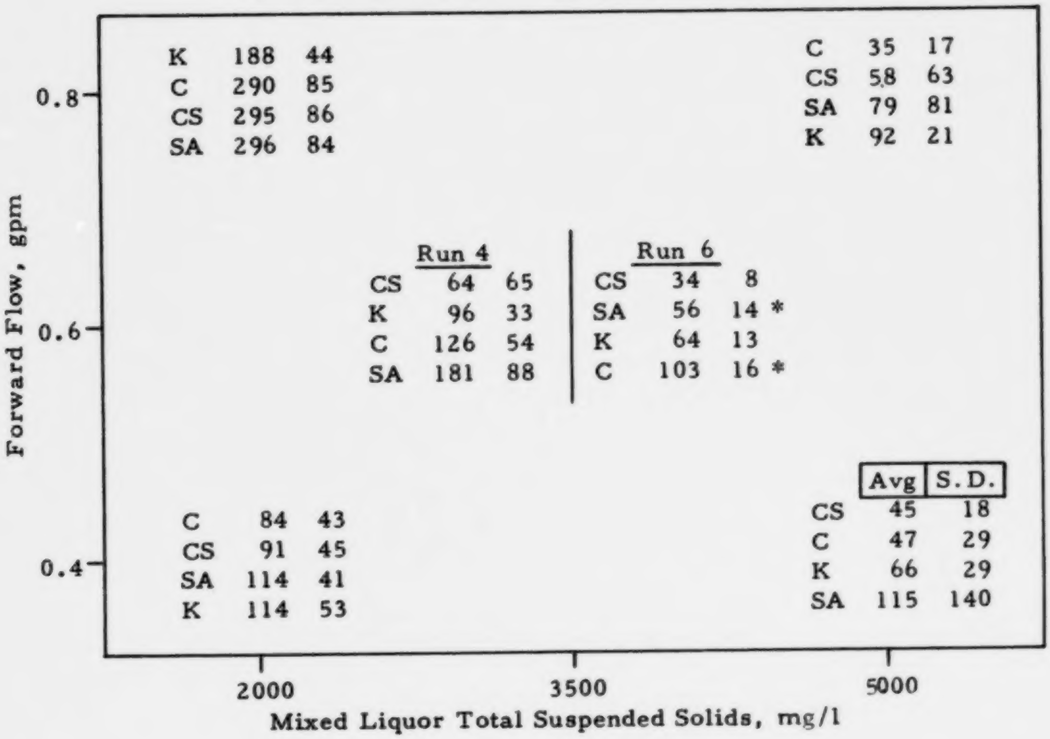


Figure 32 Page 169

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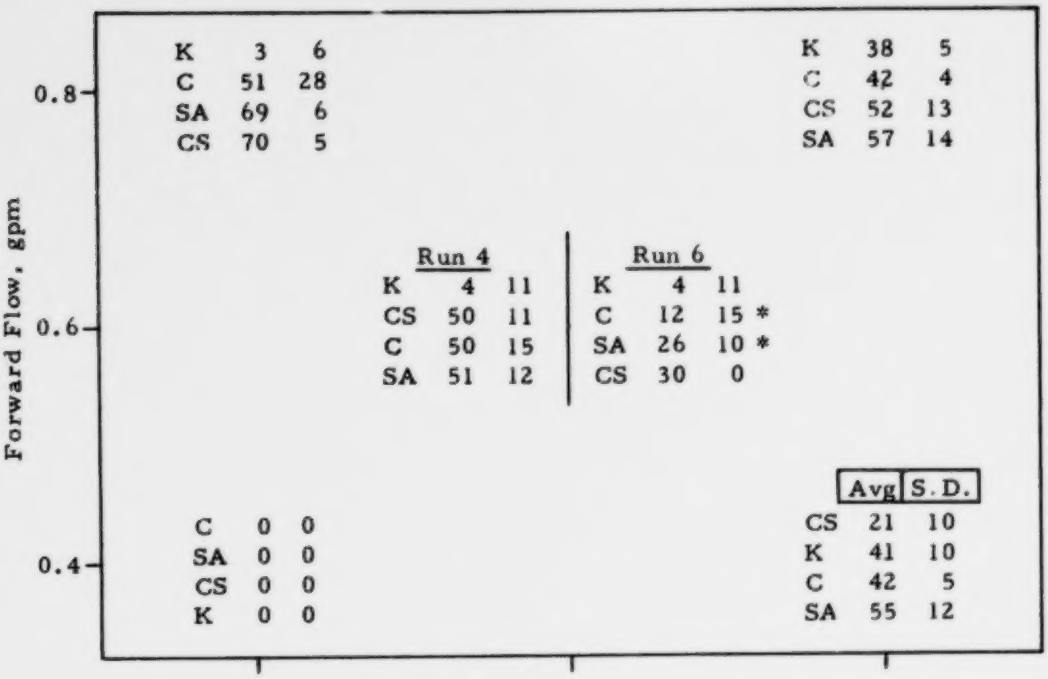
FINAL CLARIFIER SLUDGE LEVEL, (inches)



FINAL EFFLUENT COLOR, (S.U.)

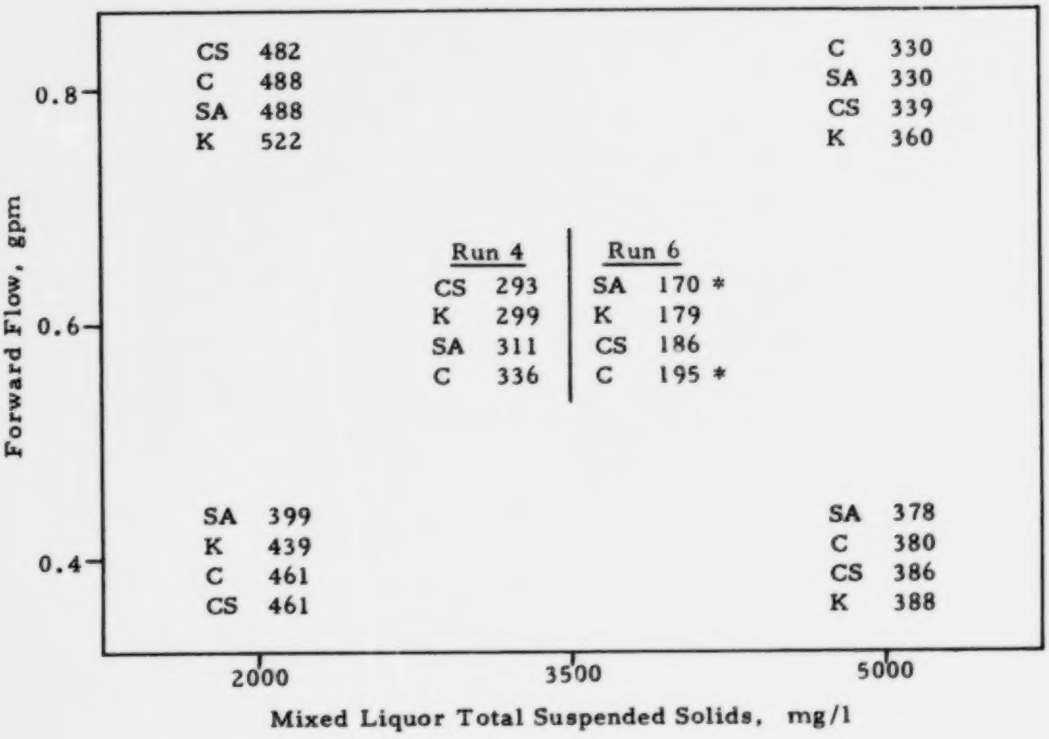


Figure 33

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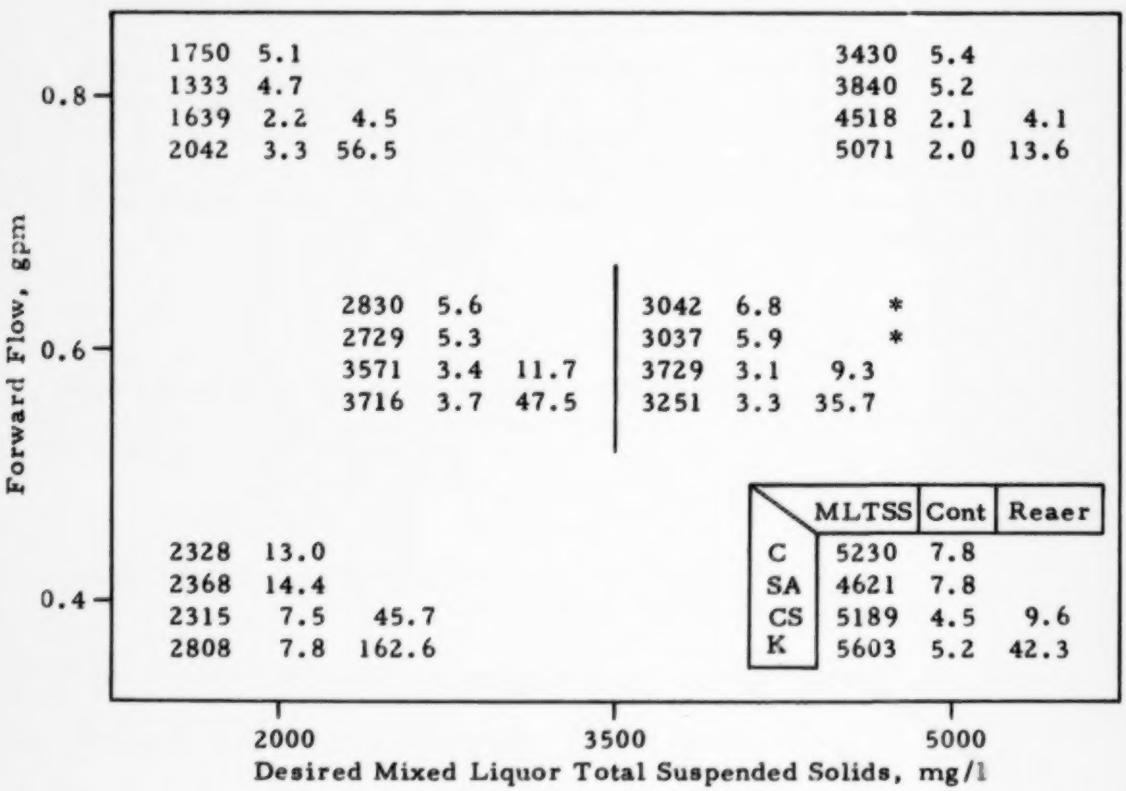

ACTUAL MLTSS (mg/l) AND DETENTION TIME (Hours)

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Figure 34

Statistical Analysis of the Response Data (17, 18)

A. Response Surface Estimation

If the two independent variables (flow and MLTSS) and the dependent variable (response) were plotted on a three-dimensional graph, a surface would be generated. Since only a limited amount of data was available for each response variable, a linear mathematical model was selected as the best first approximation to fit the response surface generated by the data. The model was of the form: $Y = b_0 + b_1$ (flow) + b_2 (TSS), where Y is the predicted response, flow is the flow rate in gpm, TSS is the mixed liquor TSS in mg/l , and b_0, b_1 and b_2 are constants.

It was found that a plane surface did not adequately describe the surface generated by the response data. The lack of fit of the model to the data was excessive due in part to the generally extreme responses which were obtained during Run 5, Condition V. Confidence limits for the coefficients were also extremely large, so that the prediction equations were of little value.

B. Analysis of Variance

Another approach, that of a simple analysis of variance (ANOVA) was then conducted. Because the processes were at similar operating conditions on each Run, and because the processes all received the same input on each Run, it was possible to consider a model of the form: $Y_{pc} = u + P_p + C_c + (PC)_{pc}$, where

Y_{pc} = Predicted value for the response variable for a given pilot plant and condition of operation.

u = The grand mean for that particular response variable.

P_p = The effect of a given pilot plant on that particular response variable.

C_c = The effect of a given operating condition on that particular response variable, and

$(PC)_{pc}$ = The interaction of the pilot plant and the operating conditions. (There were not enough data to evaluate this interaction, therefore this term was used as an error term.)

Knowledge of C_c was not considered important at this time, therefore the analyses were confined to P_p and it's effect on the response variable.

The error estimates, based on the estimated value of error from the fitted model above and also the estimate of error due to the duplicate data on Condition III, were combined to reduce the confidence limits for the response variables.

These analyses were conducted on 11 response variables; the standard deviation for the data, where replicate data existed, was also analyzed. The response variables analyzed were:

1. Final effluent filtered BOD
2. Final effluent total suspended solids
3. Final clarification
4. Filament concentration
5. Pounds oxygen required/pound BOD removed
6. Return activated sludge concentration
7. Air flotation
8. Final effluent filterability index
9. Final effluent unfiltered BOD
10. Final clarifier sludge level
11. Final effluent color

For each of the response variables the ANOVA calculations for the grand mean and its 95% confidence interval were plotted on rectangular graph paper. The 95% confidence interval for the standard deviations for final effluent unfiltered BOD and TSS, and RAS concentration were also plotted. The remaining responses either had extremely large confidence intervals for the standard deviation, or else no estimate of the standard deviation was available. The arithmetic values for the grand mean and the 95% confidence interval were plotted on the abscissa and the natural log of the standard deviation was plotted on the ordinate for the respective responses.

The following numerical values were applied to each plant for each predicted response:

0 -- The predicted value lies within the 95% confidence limits for the grand mean and the standard deviation.

±1 -- The predicted value lies outside the 95% confidence limits for the mean. (+) = on the desirable side of the grand mean; (-) = on the undesirable side of the grand mean.

-1 -- The predicted value lies outside the 95% confidence limits for the standard deviation.

A particular response could have one of the following summations:

+1 + 0 = +1
0 + 0 = 0
(+1) + (-1) = 0
(-1) + 0 = -1
(-1) + (-1) = -2

By multiplying this summation times the weighted value of the response variable (see below), total summations for the 11 response variables were obtained, as follows:

Conventional	-10
Step Aeration	-11
Contact Stabilization	-5
Kraus	-7

Because of the extreme variability of the data obtained during the six runs, these results cannot be considered absolutely conclusive. However, these analyses did indicate that the contact stabilization and Kraus processes were superior to the conventional and step aeration processes during the experimental design.

Ranking

Several sanitary engineers were requested to rank the processes for each of the thirteen responses. The response data were coded and randomized according to Plant A, B, C and D; the reviewers did not know which plant was conventional, step aeration etc. The response variables were then weighted according to their relative importance in plant design:

Response Variable	Weighted Value
Final effluent filtered BOD	10
Final effluent total suspended solids	10
Final clarification	10
Filament concentration	9
Pounds oxygen required/pound BOD removed	9
Return activated sludge concentration	7
Sludge production	7
Specific filtration resistance	5
Air flotation	5
Final effluent filterability index	5
Final effluent unfiltered BOD	3
Final clarifier sludge level	3
Final effluent color	3

By multiplying the response weight times the process rank value (4-best, 1-worst) and summing these for each process, average weighted sums were obtained as follows:

Conventional	210
Step Aeration	188
Contact Stabilization	237
Kraus	249
Maximum possible	344
Minimum possible	86

These results also indicated the contact stabilization and Kraus processes were superior to the conventional and step aeration processes. The step aeration process was eliminated from further consideration at that point, based upon the analyses of the response data and the poor operation experienced during the statistical experimental design.

Selection of Most Promising Process

The following items were taken into consideration when the results of the statistical analysis were studied:

1. There was almost continuous preaeration and prechlorination of the primary effluent feed to the conventional and step aeration units during the experimental design.

2. Although preaeration was used continuously, prechlorination was never applied to the CS unit.

3. Neither preaeration nor prechlorination were applied to the K unit.

For these reasons it is apparent that, from the stability standpoint, the K unit was superior. Had preaeration and prechlorination not been used on the C, SA and CS processes, the statistical analysis of the data would quite likely have shown a greater variation between the processes, much poorer treatment efficiencies for the conventional and step aeration units, and somewhat poorer efficiency for the CS unit.

The following subjective factors were also considered in selecting the most promising processes:

1. Stability of biological process.

2. Ability to meet all required effluent standards.

3. Effect of ambient temperature variations upon the process.

4. Versatility of the flow schematic.

5. Ease of mechanical operation.

6. Ease of plant expansion assuming no land limitations.

7. Ultimate solids disposal as related to a specific treatment process.

8. Adaptability to include advanced treatment processes at a later date.

These subjective factors are summarized as follows:

Significant Differences Exist Between the Processes

	1st	2nd	3rd
1. Process Stability	K	CS	C
2. Effluent standards:			
Filtered BOD	CS	C	K
Filterability Index	C	CS	K
3. Versatility of flow schematic	K	CS	C
4. Ease of mechanical operation	C	CS	K
5. Ease of plant expansion	C	CS	K

No Significant Differences Between Processes Are Apparent

1. Effluent standards: TSS, unfiltered BOD, color

2. Ultimate solids disposal

3. Advanced treatment adaptability

Insufficient Information Available

1. Effluent standards: nutrients

2. Effect of ambient temperature variations

One subjective factor not listed is the overall plant reliability for continuous operation, which can be differentiated from plant stability. The operating reliability of a Kraus process, which contains an aerobic and anaerobic biological system, would be expected to be less than a C, SA or CS process which has only one biological system that requires monitoring and control.

Drs. Polkowski and Boyle, of Polkowski, Boyle and Associates, Madison, Wisconsin, utilized the laboratory data obtained during the experimental design to develop theoretical full-scale design parameters for the C, CS and K flow schematics. These design parameters are summarized in Appendix F. (In some cases it was necessary to use alternate rather than the theoretical design parameters due to the resulting configuration of the full-scale units. These alternate values are also summarized in Appendix F.)

The design parameters were used by Donohue and Associates, Inc., Sheboygan, Wisconsin, to develop preliminary estimates of comparative capital and operating costs for the three plants. The flow, BOD and TSS quantities and the design scale-up parameters used in the cost estimates are presented in Appendix F. The comparative cost estimates were as follows:

	Preliminary Estimates*	
Process	Capital Costs	Operating Costs
Conventional	$15,094,000	$2,116,000
Contact Stabilization	$12,970,000	$1,559,000
Kraus	$13,005,000	$1,415,000

*(These estimates are based on 1969 dollars and do not include allowances for administration, engineering, contingencies, inflation during construction, and some facilities common to all processes.)

Utilizing the information from the statistical experimental design, the review of the subjective factors involved, and the preliminary estimates for capital and operating costs, the contact stabilization and Kraus processes were selected for additional studies during Phase III. It was decided that additional detailed information on oxygen utilization, sludge production, and sludge characteristics was necessary to select the most desirable of these two treatment processes. An effort would also be made to ascertain the reason for the biological stability of the Kraus unit to learn if this factor could be applied to the contact stabilization process.

RAS CHLORINATION - PHASE II

Upon reviewing the sulfide content in the various streams associated with the pilot plants, it was observed that a significant concentration of sulfides was present in the return activated sludge (RAS) streams. Therefore, chlorination of the RAS was started on the conventional and step aeration units January 15 and 23, 1969, respectively. The effect of this procedure on process operating parameters is shown in Figures 35 and 36. (The drop in RAS concentration for the two processes at the end of the month is due to overwasting WAS from the final clarifier.)

Note also the improved removals of TSS and unfiltered BOD characteristics of the final effluent and the improved mixed liquor settleability for Run 6 as shown in Figures 28 and 32. The significant drop in RAS-$S^=$ and filament concentrations is quite clearly shown in Figures 23 and 24. The changes in process microbiology are also presented in Tables 28 and 29.

These data illustrate that RAS chlorination was quite successful in controlling filamentous bulking problems.

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EFFECTS OF RAS CHLORINATION - CONVENTIONAL PROCESS

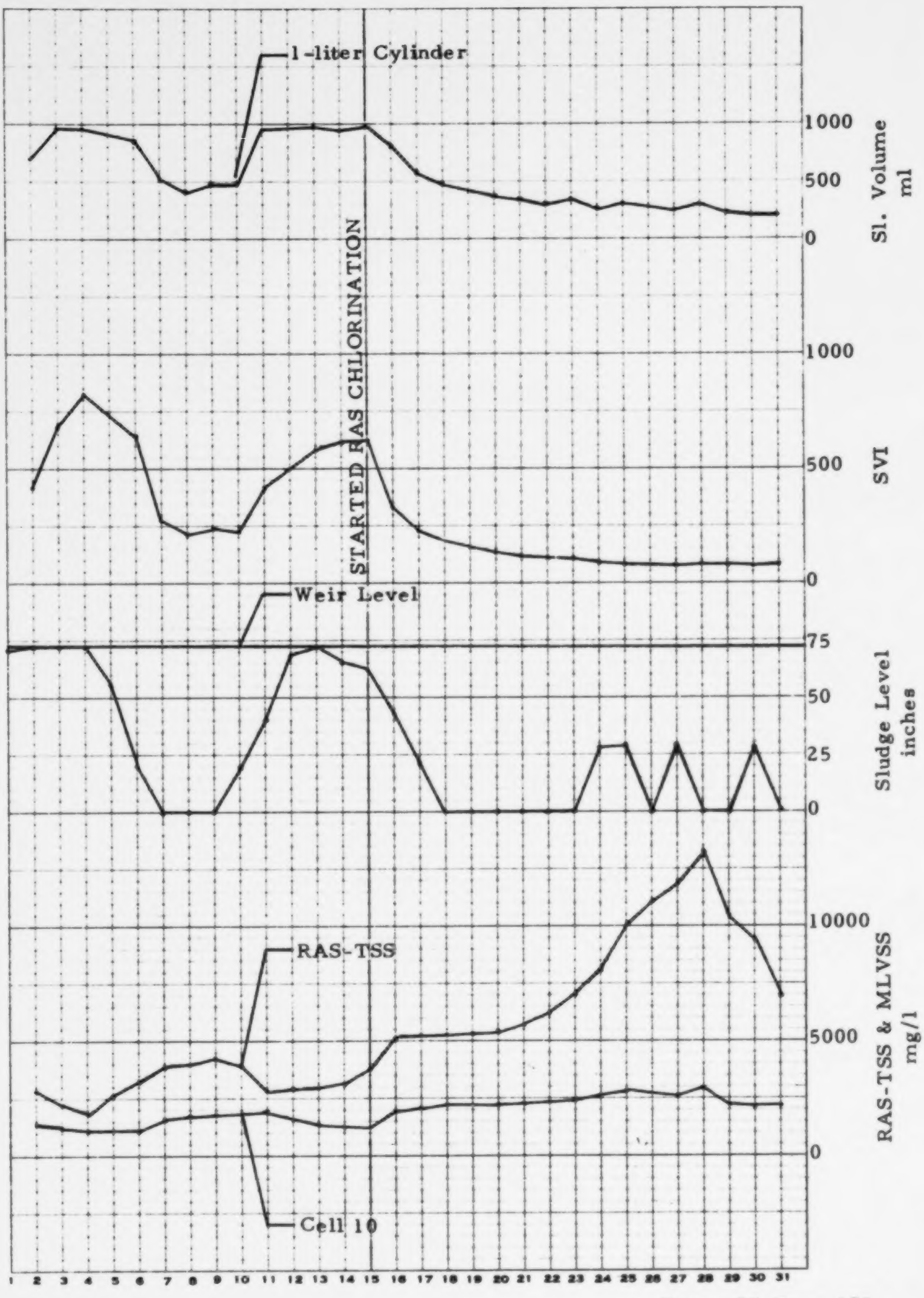

Figure 35 Page 183

MONTH January 19 69

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EFFECTS OF RAS CHLORINATION - STEP AERATION PROCESS

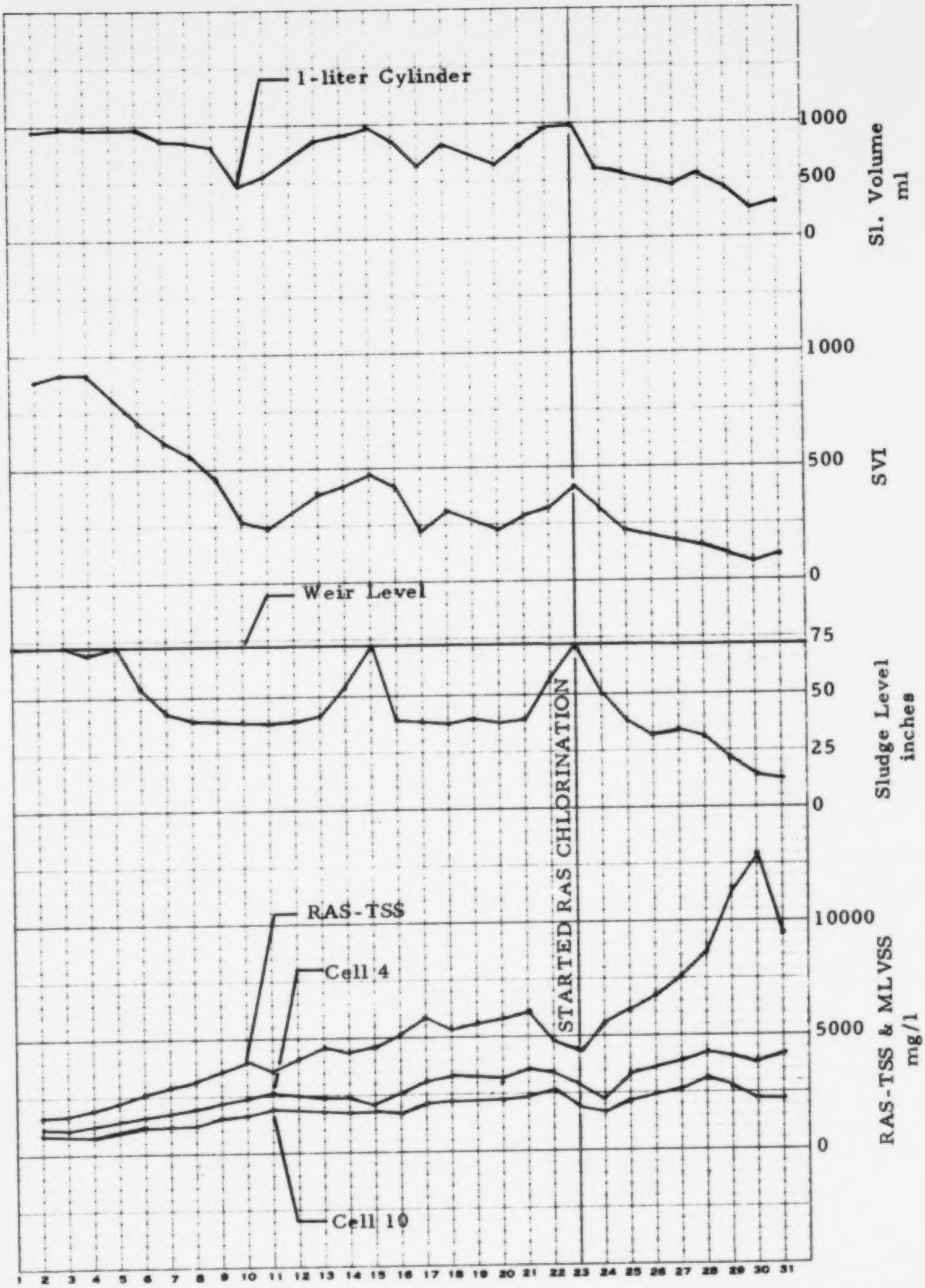

Figure 36 Page 185

MONTH January 19 69

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BIOLOGICAL ANALYSES

Date, 1969	Conventional Process
January 4	Excessive filaments present which appear to be *Sphaerotilus natans*; no $S^=$ granules present.
January 7	Filaments have decreased slightly; no $S^=$ granules.
January 11	Moderate amount of filaments present; 60% contain $S^=$ granules; appears to be a change over from *Sphaerotilus natans* to *Thiothrix.*
January 13	Excessive to epidemic amount of filaments; no $S^=$ granules; some flagellates beginning to appear.
January 15	STARTED RAS CHLORINATION
January 18	Decrease in amount of filaments; no $S^=$ granules.
January 21	Only a slight amount of filaments present; no $S^=$ granules; higher biological forms absent.
January 25	Very few filaments of any kind; no $S^=$ granules.
January 28	Trace of filaments only; biological condition greatly improved.
January 31	In good condition except for lack of higher biological life; only a trace of filaments.

BIOLOGICAL ANALYSES

Date, 1969	Step Aeration Process
January 4	Excessive filaments present which appear to be *Sphaerotilus natans*.
January 7	Excessive filaments present; no $S^=$ granules.
January 11	Slight decrease in filaments; 70% contain $S^=$ in large quantity; appears that *Thiothrix* is becoming dominant species.
January 14	Continued decrease in amount of filaments; no $S^=$ granules; many flagellates.
January 18	Increase in filaments; small amount of $S^=$ granules present.
January 21	Moderate amount of filaments present; no $S^=$ granules; no higher forms present.
January 23	STARTED RAS CHLORINATION
January 28	Only a slight amount of filaments present; no $S^=$ granules.
January 31	Only a trace of filaments present; higher biological forms present.

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PILOT PLANT RESEARCH - PHASE III

The pilot plants were shut down for cleaning and maintenance during February, 1969, having operated continuously from February 6, 1968 to February 1, 1969. The plants were started up using Metro sewage on February 24, 1969. Mill wastes were gradually added and 100% of the desired mill flow was reached on March 21, 1969.

Two pilot plant units were operated as control plants and the remaining two units were set up for variable operation. The plant designations were as follows:

	Designation	
Process	Primary	Alternate
Contact Stabilization - Variable	CS-V	A
Contact Stabilization - Control	CS-C	B
Kraus - Variable	K-V	C
Kraus - Control	K-C	D

The objectives of Phase III were to obtain additional information on:

1. Oxygen transfer and utilization
2. Sludge production
3. Methods of sludge handling
4. Optimization of operating parameters
    a. Detention time in aeration units
    b. Mixed liquor solids concentration
    c. Nutrient addition
    d. RAS chlorination

The primary response variables were:

1. Final effluent unfiltered BOD
2. Final effluent TSS
3. Filamentous microorganism population

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The control plants were operated on the basis of the theoretical full-scale design parameters developed at the completion of the statistical experimental design. The operating parameters for the variable plants were chosen to minimize the volume of the aeration units (and not exceed an F/M ratio of 0.4) while maintaining the final clarifier loadings within an acceptable operating range. The designs were also selected to have $S_a t$ (MLVSS x contact section detention time) values within the range of those selected for the first preliminary cost estimate.

The pilot plant operating parameters for the initial startup are presented in Table 30, flow schematics in Figures 37 and 38, and the relationship between RAS chlorination and filament concentration in Figure 39. (See Phase I for nomenclature on Figure 39.)

The average BOD and TSS removals for Phase III, excluding startup during March, are presented in Table 31. Except for March, the plants were operated quite closely to the theoretical parameters.

Summary of Pilot Plant Operation During Phase III

March

Due to the slow build-up of biological solids, waste activated sludge from the Kraus plants was added to the CS-V plant. By April 1, the CS plants had reached the desired solids concentration in the contact sections of the aeration units. The Kraus units developed solids quite rapidly and operated well during March. It was necessary to begin RAS chlorination of the CS-V unit about mid-March in order to inhibit the growth of the filamentous microorganisms. This was quite successful and the plant continued to operate in a normal manner.

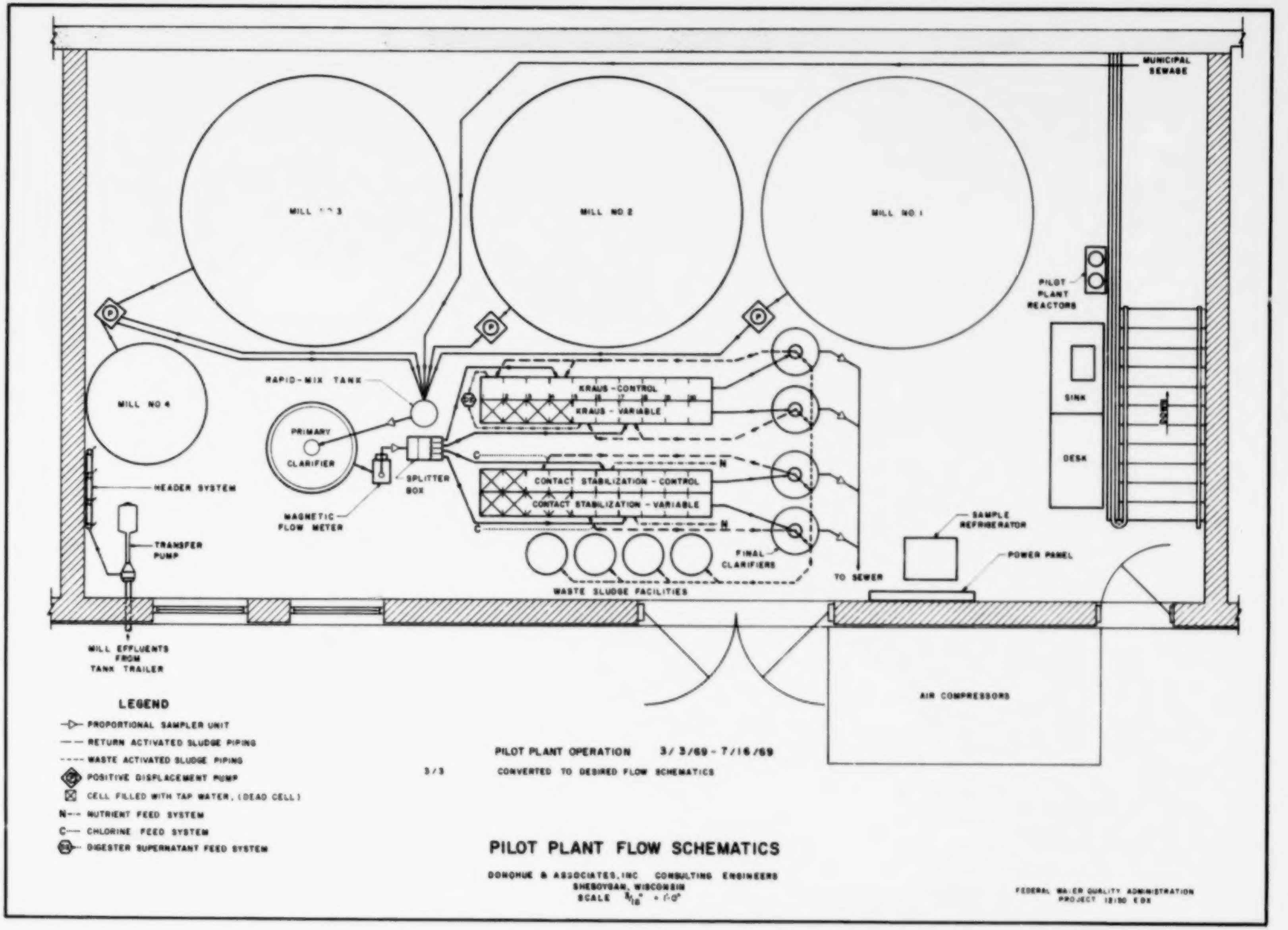
April and May

The CS-V, CS-C and K-V units had no operational problems although the CS-C plant did contain excessive filamentous microorganisms at various times during April. To counteract the excessive filaments, RAS chlorination was started April 10 and this was successful in reducing the filament population.

THEORETICAL PILOT PLANT OPERATION - PHASE III

February 24 - July 31, 1969

Parameter	CS Variable	CS Control	K Variable	K Control
Q Forward, l/d	4310	4310	4310	4310
MLTSS, mg/l	4550	3980	5370	4370
MLVSS, mg/l	4000	3500	4300	3500
RAS-TSS, mg/l	9100	9100	12500	12500
RAS-VSS, mg/l	8000	8000	10000	10000
R/Q	1.0	0.78	0.78 $R_n = 20\%$ $R_c = 80\%$	0.54 $R_n = 20\%$ $R_c = 80\%$
D_t-Contact, hrs.	1.9	2.7	2.2	4.3
D_t-Reaeration, hrs.	1.9	4.6	12.6	26.4
S_{at}, mg/l-hr.	7600	9270	9270	15050
F/M	0.35	0.27	0.31	0.21
Nutrient Addition	BOD:N:P 100:5:1	BOD:N:P 100:5:1		
Dig. Sup. Addition			BOD:P 100:0.8	BOD:P 100:0.8


MUNICIPAL SEWAGE
MILL NO 3
MILL NO 2
MILL NO 1
MILL NO 4
PILOT PLANT REACTORS
SINK
DESK
RAPID-MIX TANK
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
KRAUS - CONTROL
KRAUS - VARIABLE
CONTACT STABILIZATION - CONTROL
CONTACT STABILIZATION - VARIABLE
C
N
FINAL CLARIFIERS
WASTE SLUDGE FACILITIES
TO SEWER
SAMPLE REFRIGERATOR
POWER PANEL
AIR COMPRESSORS
MILL EFFLUENTS FROM TANK TRAILER
3/3

LEGEND

- ▷ PROPORTIONAL SAMPLER UNIT
- —— RETURN ACTIVATED SLUDGE PIPING
- - - - WASTE ACTIVATED SLUDGE PIPING
- ◈ POSITIVE DISPLACEMENT PUMP
- ☒ CELL FILLED WITH TAP WATER, (DEAD CELL)
- N--- NUTRIENT FEED SYSTEM
- C—— CHLORINE FEED SYSTEM
- ⊛ DIGESTER SUPERNATANT FEED SYSTEM

PILOT PLANT OPERATION 3/3/69 - 7/16/69
CONVERTED TO DESIRED FLOW SCHEMATICS

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE 3/16" = 1'-0"

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 37 PAGE 195

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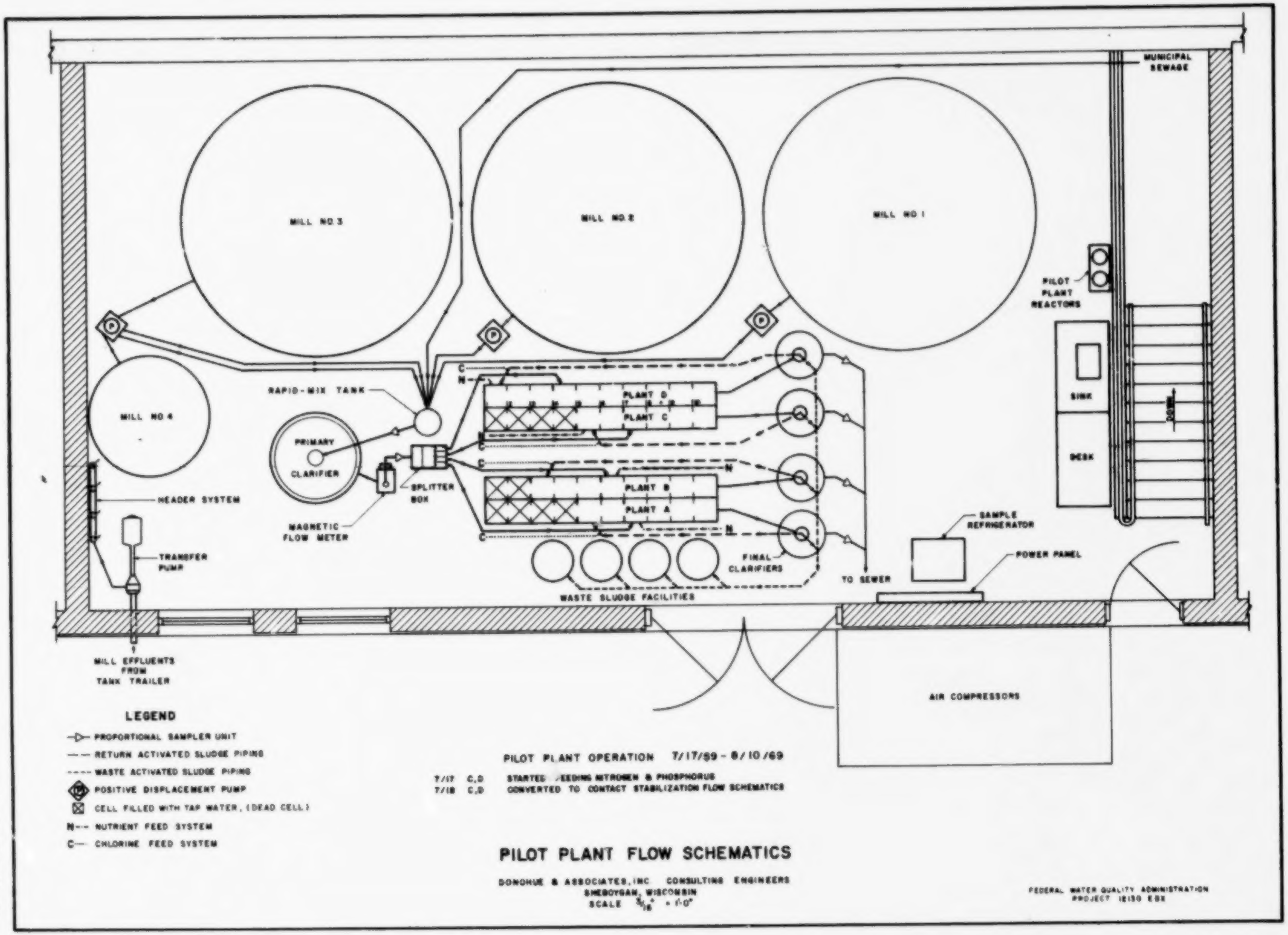
MUNICIPAL SEWAGE
MILL NO.3
MILL NO.2
MILL NO 1
MILL NO.4
PILOT PLANT REACTORS
SINK
DESK
DOWN
RAPID-MIX TANK
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
HEADER SYSTEM
TRANSFER PUMP
PLANT D
PLANT C
PLANT B
PLANT A
C
N
FINAL CLARIFIERS
WASTE SLUDGE FACILITIES
TO SEWER
SAMPLE REFRIGERATOR
POWER PANEL
AIR COMPRESSORS
MILL EFFLUENTS FROM TANK TRAILER

LEGEND

- —▷— PROPORTIONAL SAMPLER UNIT
- — — RETURN ACTIVATED SLUDGE PIPING
- - - - WASTE ACTIVATED SLUDGE PIPING
- ◈ POSITIVE DISPLACEMENT PUMP
- ☒ CELL FILLED WITH TAP WATER, (DEAD CELL)
- N--- NUTRIENT FEED SYSTEM
- C— CHLORINE FEED SYSTEM

PILOT PLANT OPERATION 7/17/69 - 8/10/69

7/17 C,D STARTED FEEDING NITROGEN & PHOSPHORUS
7/18 C,D CONVERTED TO CONTACT STABILIZATION FLOW SCHEMATICS

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE $\frac{3}{16}$" = 1'-0"

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FIGURE 38 PAGE 197

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PILOT PLANT OPERATION - PHASE III - 3/1/69 TO 7/31/69

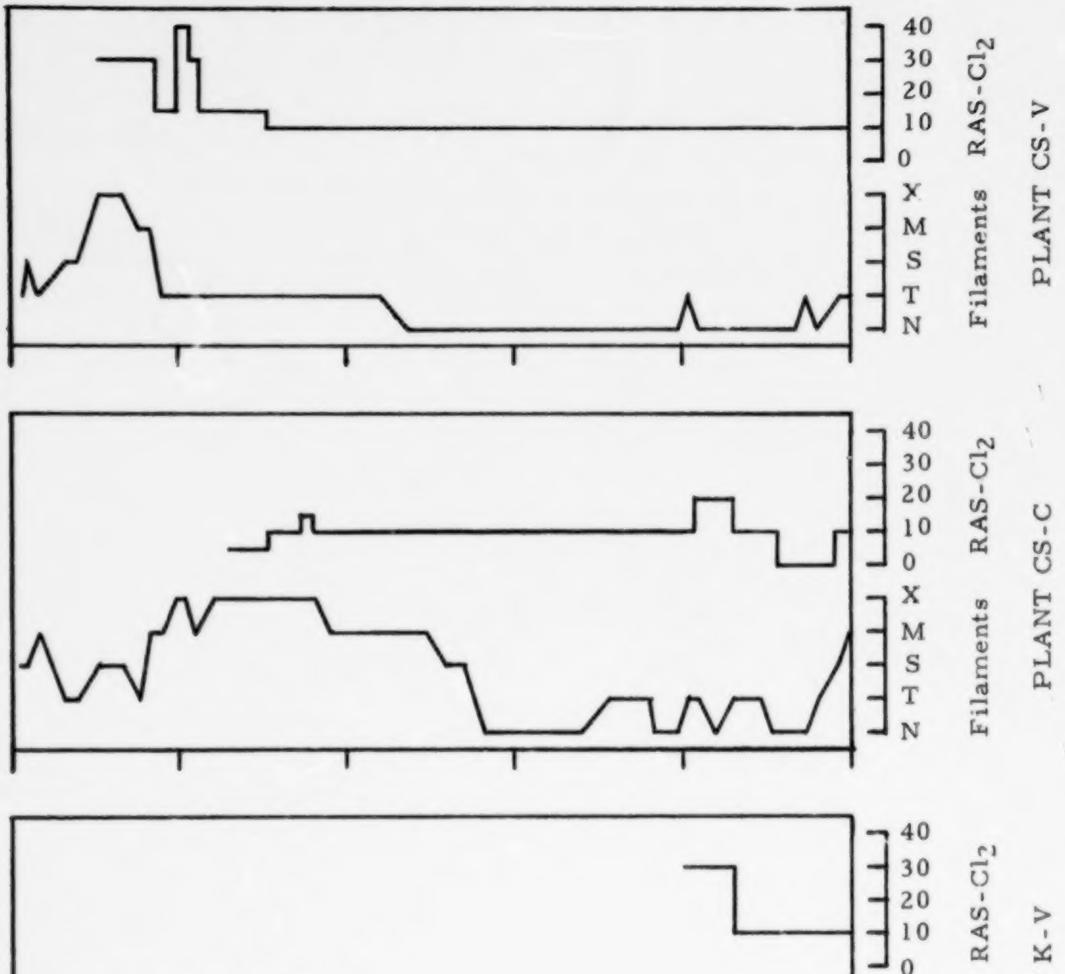

Figure 39 Page 199

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BOD AND TSS REMOVAL - PHASE III

April 1 - July 31, 1969

	mg/l		Percent Removal*	
	BOD	TSS	BOD	TSS
Primary Influent	526	222		
Primary Effluent	488	165	7.2	25.7
Final Effluent*				
Contact Stabilization - Variable	46	54	90.6	61.2
Contact Stabilization - Control	51	59	89.5	64.2
Kraus - Variable	65	79	86.7	52.1
Kraus - Control	77	134	84.2	18.8

*The final effluent percent removals are based on the difference between PE and FE values; the values shown are secondary treatment removal efficiencies only.

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The K-C operation during April and May was as follows:

4/1-4/20	Normal operation.
4/21	Increase in unfiltered BOD in FE.
4/22	Sludge blanket began rising in final clarifier.
4/23	RAS concentration began decreasing; excessive filaments containing a significant amount of sulfur granules were present in mixed liquor.
4/26	Significant increase in TSS in FE.
4/28	Sludge blanket went over weir; sludge blanket level reduced by slug-wasting WAS; filaments were breaking up, were branched, and contained less sulfur granules.
4/30	Increased the digester supernatant feed to about 140% of average flow rate.
5/1	Bypassed 20% of PE feed to reduce F/M ratio; increased digester supt. feed to about 190% of average flow rate; sludge blanket over weir.
5/5	Increased digester supt. feed to about 240% of average flow rate; moderate amount of branched filaments present - some sulfur granules.
5/6	Bypassing of PE feed increased to 25%. There was no noticeable effect on the filamentous bulking problem due to the increased digester supernatant feed.
5/8	Began RAS chlorination at 25 mg/l.
5/9	Decreased digester supernatant feed to average flow rate. A significant drop in sludge blanket, BOD and TSS in FE, and increase in RAS concentration occurred.
5/10	Stopped bypassing PE feed.
5/12	Reduced RAS-Cl_2 to 15 mg/l; filaments were breaking up and were less branched.
5/13	Reduced RAS-Cl_2 to 10 mg/l.

5/22 Stopped RAS-chlorination; only a slight number of filaments present.

5/28 RAS concentration was about 30,000 mg/l and sludge blanket level at 16 inches.

The CS-V, CS-C, and K-V plants operated well during May. Based upon the May laboratory data, the CS-V plant had the best BOD removal efficiency. If an inexplicably high daily value of 624 mg/l TSS in the FE for CS-V is eliminated from the monthly data, then this plant also had the best TSS removal efficiency.

The bulking of the K-C plant due to filamentous microorganisms was the first occurrence since recovery of the Kraus unit after the upset in March, 1968. This latest event was unexpected due to the stable biological operation of the Kraus unit during Phases I and II. One of the primary reasons for continuing the study of the Kraus process was the fact that it was not prone to excessive growths of filamentous microorganisms during the first year of operation.

Based on the experience in the K-C plant, the conclusion was reached that RAS chlorination was much more effective than digester supernatant addition for the control of sulfur-containing filamentous microorganisms.

June

A cursory examination of the effect of nutrient deficiency on process operation was conducted during June and July. On June 17 the supplemental feed rate of N and P to the CS plants was reduced to 50% of the normal values and on June 18 the digester supernatant feed rate to the K units was reduced to 75% of the normal values. On June 24, the supplemental nutrient feed (including the digester supernatant) to all the plants was reduced to zero.

The CS plants and the K-C plant operated well during June. The K-V unit had operational problems during the last half of June. On June 17, 23, and 26, WAS was slug-wasted in an effort to keep the sludge blanket below the weir. The split of RAS was also changed to return 50% to the nitrifying section and 50% to the contact section in an effort to obtain a lower sludge blanket in the final clarifier. None of these operations resulted in a continuously lower sludge blanket. The fact that no digester supernatant was being added after June 24 no doubt aggravated the situation.

In summary, the K-C unit had the best BOD and total suspended solids removals during June, followed by the two CS units which performed about equally well. The K-V unit had a slightly lower efficiency, than the CS units.

July

CS-V

July 28	Supplemental P addition, at BOD:P ratio of 100:0.6, started in an attempt to create a better settling floc.

CS-C

July 18	Arbitrarily stopped RAS chlorination.
July 22	Settled sludge volume in SVI test began to increase.
July 23	Settled sludge volume exceeded 900 ml.
July 28	Began RAS chlorination and supplemental P addition.

Both K units operated without digester supernatant feed, July 1 to 18. On July 18, the plants were changed to the CS flow schematic by returning all RAS to the reaeration section.

K-V

July 1	Began RAS chlorination to counteract high sludge blanket.
July 5	Changed RAS split to 100% to reaeration section.
July 16	Changed RAS split to 20%-reaeration, 80%-contact; no beneficial effects due to previous setting.
July 17	Began supplemental P feeding.
July 19	Significant increase in RAS concentration.
July 24	Sludge blanket began to subside.

K-C

July 1	No sludge blanket visible.
July 8	Sludge blanket visible and increasing rapidly.
July 17	Began supplemental P addition at BOD:P ratio of 100:0.6.
July 19	Sludge blanket over weir.
July 28	Began RAS chlorination.
July 31	Slight increase in RAS concentration.

The CS-V unit had the best BOD and TSS removal efficiency. The CS-C unit had a somewhat poorer treatment efficiency than CS-V, while both K units experienced problems with sludge going over the final clarifier weirs. The CS units operated without any apparent detriment due to the reduction of supplemental nutrient feedings; the two Kraus units exhibited a poor-settling sludge and on July 17 the sludge went over the weirs in both the K-V and the K-C plants. The poor-settling sludge was not due to filamentous microorganisms, as in the past, but was due to the characteristics of the floc which would not allow it to settle and compact.

In general, RAS chlorination of the K-V unit had little effect on decreasing the sludge blanket and increasing the RAS concentration. The P addition appeared to have a more significant effect in improving these parameters in this plant. The P addition to the K-C unit did not cause a significant improvement as in the K-V unit. The slight increase in the RAS concentration and small drop in the sludge blanket level at the end of July were apparently due to the RAS chlorination.

In conclusion, the operation of the K units during July indicated that RAS chlorination is not effective in controlling non-filamentous bulking problems.

Special Laboratory Studies

Special studies conducted on the four plants during May and June, in addition to the normal laboratory routine, were as follows:

1. Oxygen uptake
2. Oxygen transfer

3. Sludge production

4. Air flotation of waste activated sludge

5. Gravity thickening of waste activated sludge, and WAS plus primary clarifier sludge

6. Specific filtration resistance of WAS plus primary clarifier sludge

7. Anaerobic sludge digestion

8. Return of waste activated sludge to the pilot clarifier

9. BTU value of sludges

10. Chlorine demand of final effluents

Items 8, 9 and 10 are discussed in the Sections entitled Primary Clarification, BTU Value of Sludges, and Chlorine Demand of Final Effluents, respectively.

The laboratory data for items 1 through 6 are presented in Table 32; comments on these tests are as follows:

Oxygen Uptake

The oxygen uptake studies were conducted on composite samples of aeration tank mixed liquor and return activated sludge, and on primary effluent which had previously been transferred to a laboratory reactor. The effective detention time in the reaeration zone was selected to be the same as the total detention time in the contact zone for oxygen uptake study purposes. (The contents of reaeration zone undergo the same time of aeration as the contents of the contact zone to remove a given unit of BOD.)

The two values shown for the oxygen uptake rates are (1) the initial rate at the beginning of the test and (2) the final rate at the conclusion of the test. The two values shown for the BOD concentration measured during the oxygen uptake studies are (1) the initial theoretical calculated value for the composite sample, and (2) the final measured BOD in the reactor at the conclusion of the test.

Oxygen Transfer

The oxygen transfer studies were conducted utilizing grab samples from

SPECIAL LABORATORY STUDIES - PHASE III

	Contact Stabilization-Variable			Contact Stabilization-Control				Kraus-Variable			Kraus-Control		
O_2 UPTAKE	5/7	5/22	6/4	5/8	5/21	5/29	6/5	5/9	5/19	6/6	5/12	5/20	6/9
REAERATION ZONE													
Effective D. T., hr.	2. 31	2. 58	2. 41	3. 16	3. 27	3. 18	3. 51	2. 43	2. 59	2. 85	4. 20	4. 65	5. 36
MLVSS, mg/l	8634	9908	7750	10128	9652	10828	8310	12750	10388	11452	8084	12222	7864
Uptake Rate, mg/l/hr.	165,75	88;55	71;47	204;58	81;52	180;74	68;52	258;109	213;89	309;101	96;66	120;75	171;72
CONTACT ZONE													
Total D. T., hr.	2. 31	2. 58	2. 41	3. 16	3. 27	3. 18	3. 51	2. 43	2. 59	2. 85	4. 20	4. 65	5. 36
MLVSS, mg/l	4174	4110	3996	4056	1656	5010	3862	4870	3974	3954	4436	4606	2596
Uptake Rate, mg/l/hr.	528:100	288;52	192;53	402;50	96;30	330;58	165;36	396;62	312;42	330;47	111;43	264.36	78;47
BOD conc., mg/l	332;38	424;20	338;26	322;15	437;102	419;41	363;51	357;25	460;55	356;27	403;51	353;17	548;62
Lbs. O_2 Required / Lb. BOD Removed	2. 51	0. 82	1. 18	2. 02	0. 84	1. 81	1. 14	1. 70	1. 11	1. 52	1. 47	1. 70	1. 30
O_2 TRANSFER	5/13	5/23	6/10	5/13	5/23	6/10		5/13	5/23	6/10	5/13	5/23	6/10
REAERATION ZONE													
Alpha (α)	. 57;. 80	1.15;. 66	1. 40;. 61	.81;. 88	. 83;1. 25	. 95;1. 52		. 68;. 74	. 61;. 78	. 60;. 70	. 86;. 60	. 58;. 66	. 80. 59
Beta (β)	. 90;. 85	. 93;. 93	90;. 87	. 83;. 84	. 90;. 89	. 97;. 92		. 75;. 78	. 78;. 84	. 59;. 81	. 83;. 82	. 82;. 92	. 82;. 83
CONTACT ZONE													
Alpha (α)	. 70;. 85	. 73;. 81	1. 05;1. 20	. 80;. 93	. 72;. 92	. 56;. 81		. 73;. 83	. 87;1. 05	. 79;. 76	. 82;. 81	. 86;1. 12	. 55;. 88
Beta (β)	. 80;. 93	. 96;. 98	. 80;. 95	. 73;. 94	. 93;. 93	1. 13;. 85		. 81;. 91	. 91;. 94	. 74;. 88	. 64;. 88	. 97;. 98	. 83;. 90
SOLIDS PRODUCTION	5/5-12	5/19-26	6/4-11	5/5-12	5/19-26	6/4-11		5/5-12	5/19-26	6/4-11	5/5-12	5/19-26	6/4/11
Lbs TSS Produced / Lb BOD Removed	0. 68	0. 46	0. 69	0. 50	0. 52	0. 68		1. 21	0. 89	1. 46	1. 13	0. 80	1. 20

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SPECIAL LABORATORY STUDIES - PHASE III

	Contact Stabilization-Variable					Contact Stabilization-Control					Kraus-Variable				Kraus-Control		
AIR FLOTATION	5/1-15	5/16-31	6/1-15			5/1-15	5/16-31	6/1-15			5/1-15	5/16-31	6/1-15		5/1-15	5/16-31	6/1-15
WAS concentration, mg/l	10656	11652	8420			9392	11620	10448			10972	13824	15020		11548	15740	14904
(Duplicate Test)	10656	11652	8420			9392	11620	10448				13824	15020		11548	15740	14904
Final Concentration, mg/l	28957	26702	25458			17151	25661	28595			20573	21799	15020		23524	24215	21425
(Duplicate Test)	30636	23304	23913			23276	21949	26866				18816	13232		20665	22298	24592
Rate of Ascent, ft/min	0.578	0.688	0.504			0.554	0.806	0.451			0.285	0.205	0.214		0.261	0.318	0.491
(Duplicate Test)	0.475	0.332	0.415			0.332	0.368	0.320				0.257	0.148		0.186	0.435	0.448
Pressurized Flow Volume: Sample Volume	3.00:1	2.65:1	2.89:1			3.76:1	2.81:1	2.88:1			2.33:1	4.00:1	6.65:1		2.65:1	4.00:1	7.70:1
(Duplicate Test)	1.90:1	1.78:1	1.77:1			2.56:1	1.94:1	1.81:1				3.12:1	4.46:1		1.94:1	2.96:1	5.06:1
GRAVITY THICKENING	5/14	5/26	6/11	6/3	6/6	5/14	5/26	6/11	6/13	6/10	5/14	5126	6/6	6/12	5/15	6/9	6/13
Sample Composition	A*	A	A	B	B	A	A	A	B	B	A	A	A	B	A	A	B
Volume Ratio-WAS:PC				8:1	14.7:1				8:1	13:1			10.6:1			7.8:1	
Initial Conc., mg/l	9682	7992	12532	10168	17652	11236	11960	8712	17856	14736	14684	16260	21020	19224	14964	16108	17000
Final Conc., mg/l	23052	28543	29144	21406	43054	23655	23223	26806	35012	35086	25761	25015	29194	40050	30230	33076	38636
Length of Test, min.	165	120	180	180	180	150	120	180	180	240	150	140	360	240	225	240	240
Supernatant Analyses:																	
BOD, mg/l			132	290	90			68	154	109			160	160		110	227
TSS, mg/l			124	232	128			72	236	100E			124	216		124	224
SFR (BUCHNER FUNNEL)	5/14	5/26				5/14	5/26				5/14	5/26			5/14	5/26	
Sample Composition	B	B				B	B				B	B			B	B	
Volume Ratio-WAS:PC	3:1	3:1				3:1	3:1				3:1	3:1			3:1	3:1	
Total Solids Conc., mg/l	30260	32750				31000	31380				32330	31740			32670	38270	
SFR x 10^7 sec^2/gram	274	104				345	115				334	278			216	579	

* A = WAS; B = WAS + PC

the particular cells in the pilot plant units. The two values shown for Alpha and Beta are the values for the first cell and the last cell respectively of the reaeration zone or the contact zone.

Sludge Production

The procedure for calculating the sludge production is described in Appendix B. The only difference is the time period used for the calculation.

The solids production calculations for the Kraus units include the total suspended solids contributed by the digester supernatant but do not include the BOD associated with the digester supernatant.

Air Flotation

The air flotation studies on WAS utilized the samples as obtained; they were not diluted with final effluent as were the samples studied during Phase II. No chemicals were added during the air flotation studies.

Gravity Thickening

The tests were conducted on two sets of samples:

a. Grab samples of waste activated sludge.

b. Grab samples of waste activated sludge plus grab samples of primary clarifier sludge mixed together in the volumetric ratios shown in the Table.

The laboratory procedure used for these studies is presented in Appendix B.

Specific Filtration Resistance

Individual samples of WAS and primary clarifier sludge were prethickened and combined as follows:

a. Grab samples of primary clarifier sludge thickened in a 1-liter cylinder, without stirring, for 30 minutes.

b. Grab samples of WAS thickened in 1-liter cylinder, with stirring, for 3 hours.

c. The two thickened samples were composited in a volumetric ratio of one part primary sludge to three parts WAS.

d. If the primary sludge grab sample was at least 3% TSS, it was not prethickened.

The specific filtration resistance data indicated that none of the raw sludges analyzed could be filtered economically without sludge conditioning.

Sludge Digestion

Three laboratory digesters were set up as follows:

1. Digester #1 - Received GBMSD primary clarifier sludge.
2. Digester #2 - Received pilot clarifier sludge which contained WAS from K-C (May 1-June 30; Phase A) or CS-C (July 1-July 31; Phase B).
3. Digester #3 - Received a composite of pilot plant primary clarifier sludge and thickened WAS from K-C unit.

The #3 digester was fed at a ratio of one pound of primary clarifier sludge VSS to every three pounds of WAS-VSS. The desired loading rate was 0.1 pound of VSS per cubic foot per day.

Gas production and total and volatile solids added and removed from each digester was measured daily. pH, alkalinity and volatile acids were monitored routinely. Cubic feet of gas produced per pound of volatile solids reduced and the reduction in volatile solids were also calculated.

The laboratory digester studies showed that the particular combinations of sludges were readily digestable with good gas production. The values obtained from Digester #1 (being fed GBMSD primary clarifier sludge) compared quite well with those values obtained for the full-scale treatment plant digesters.

Graphs of selected operating parameters for the laboratory digesters are presented in Figure 40. Photographs of the experimental equipment are shown in Figure 41.

LABORATORY DIGESTER STUDIES, MAY-JULY, 1969
PLOT OF SELECTED PARAMETERS vs. TIME

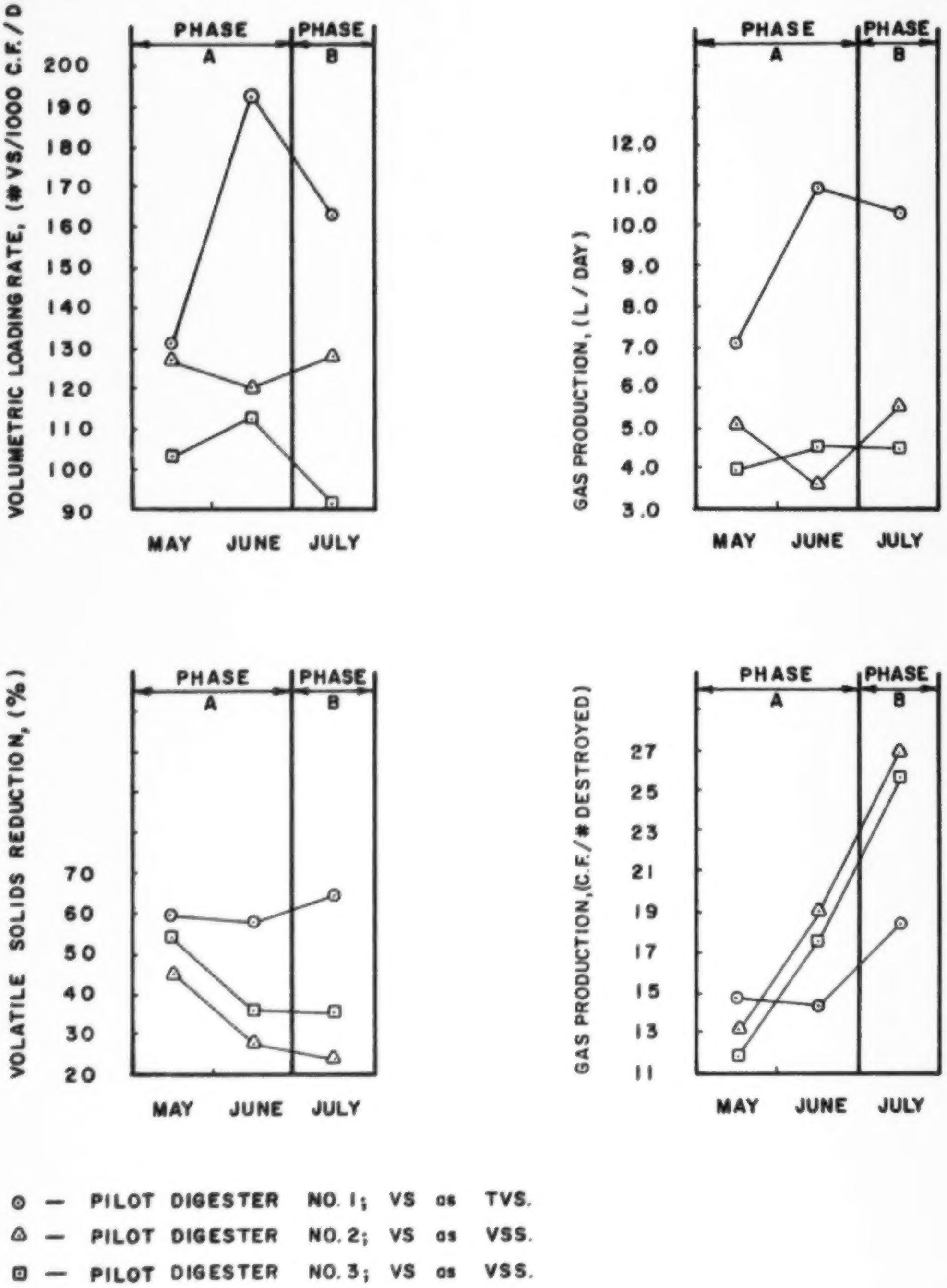

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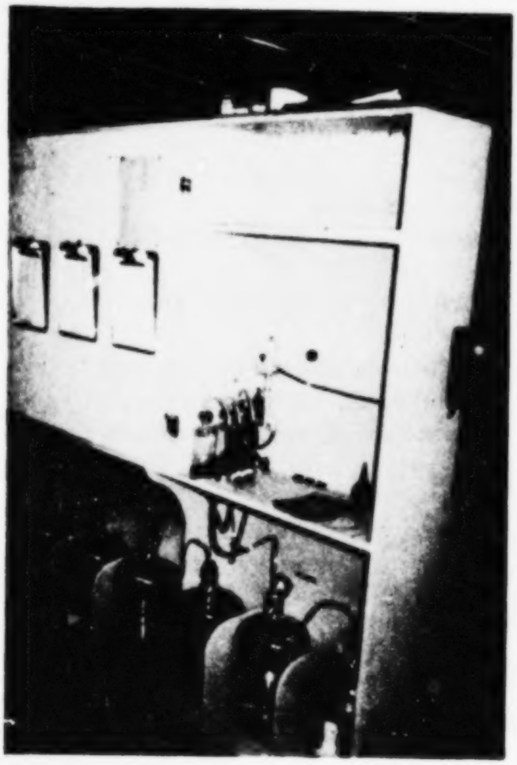
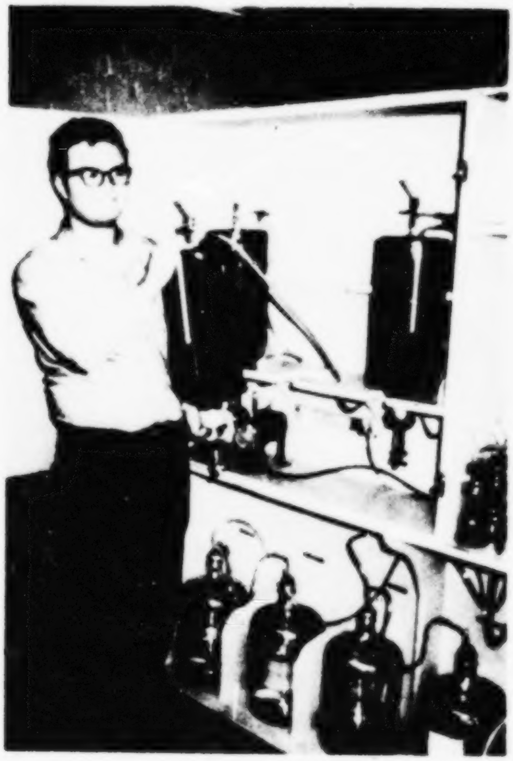
FIGURE 40

LABORATORY DIGESTER EQUIPMENT



EXTERIOR VIEW OF INCUBATOR. GAS COLLECTION BOTTLES SHOWN AT BOTTOM OF PHOTO.



REACTOR CONTENTS BEING MIXED AFTER FEED HAS BEEN ADDED.

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FIGURE 41

Selection of the Most Promising Process

The laboratory data obtained both from the daily pilot plant operation and the special studies conducted between May 1 and June 15 were utilized to develop theoretical full-scale design parameters. (See Appendix F). These parameters were then utilized to develop preliminary comparative capital and operating cost estimates for full-scale contact stabilization and Kraus plants. (See Appendix F for the flow, BOD and TSS quantities, and design scale-up parameters used in the cost estimates.)

The estimated comparative costs were as follows:

	Preliminary Estimates*	
	Capital Cost	Operating Cost
Contact Stabilization	$16,262,000	$2,094,000
Kraus	$18,409,000	$2,262,000

*(These estimates are based on 1969 dollars and do not include allowances for administration, engineering, contingencies, inflation during construction, and some facilities common to both processes.)

The following factors were also considered in selecting the most optimum process:

1. Metro and Mill 3 wastes would be combined in an existing interceptor sewer; the wastes from Mills 1, 2, and 4 would be conveyed to the treatment plant in a separate sewer. All wastes would receive primary treatment during average flow; during peak storm flow conditions the wastes from Mills 1, 2, and 4 would be pumped directly to secondary treatment.

2. Anaerobic sludge digestion is a potentially troublesome unit operation.

3. The use of digester supernatant feed for filamentous control was not entirely successful. Also, a situation of excess phosphorous feed to the process could occur when attempting to use digester supernatant for biological control.

4. RAS chlorination was successful in controlling the filamentous

microorganisms in both flow schematics. Since receiving RAS chlorination, the CS unit was the more stable of the two processes.

5. The K unit had a lower sludge production rate than the CS unit.
6. The CS unit has a simpler flow schematic and thus would be easier to control.
7. The CS process had superior BOD and TSS removal efficiencies during Phase III.
8. The preliminary cost estimate was based upon CS and K plant designs which would provide equivalent treatment.
9. The CS process had the lower estimated capital and operating costs.

Based upon the preceding information, the contact stabilization process was selected for the proposed full-scale treatment plant.

PILOT PLANT RESEARCH - PHASE IV

On July 18, the two Kraus units were converted to contact stabilization flow schematics. All four pilot plants then had the same flow schematic.

The plants were assigned the following identification symbols:

New Designation	Previous Designation
Plant A	Contact Stabilization-Variable
Plant B	Contact Stabilization-Control
Plant C	Kraus-Variable
Plant D	Kraus-Control

The major objectives of Phase IV were to obtain refined design parameters pertaining to:

1. Oxygen transfer and utilization
2. Sludge production
3. Methods of primary clarifier and waste activated sludge conditioning and disposal.

In addition, the following operating situations were studied:

1. Elimination of Mill 3 waste from pilot plant influent.
2. Increased hydraulic loadings to approximate storm flow conditions.
3. Bypassing of Mill 1, 2 and 4 wastes around primary clarification directly to the secondary system.

The four plants were utilized as follows to accomplish these objectives:

Plant A

Between September 1 and October 19, the pilot clarifier was connected directly to Plant A. Plant A was then operated such that Metro sewage only was receiving primary treatment and Mill 1, 2 and 4 wastes were added to the pilot clarifier effluent.

The high-flow studies began October 3 by increasing the Metro sewage flow. Between October 7 and October 19, tap water was added to the Metro sewage to reduce the BOD to approximately 100 mg/l, simulating a storm flow condition. (Refer to the section entitled "Primary Clarification" for pilot clarifier flow schematics and operating data.) The pilot clarifier was taken out of service on October 20. Between October 20 and December 15,

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Plant A then received the full complement of Mill and Metro feed and was used for miscellaneous studies.

Plant B

This plant was operated as a reserve unit to provide additional WAS for the solids handling studies. Some miscellaneous studies were also conducted on this plant.

Plants C and D

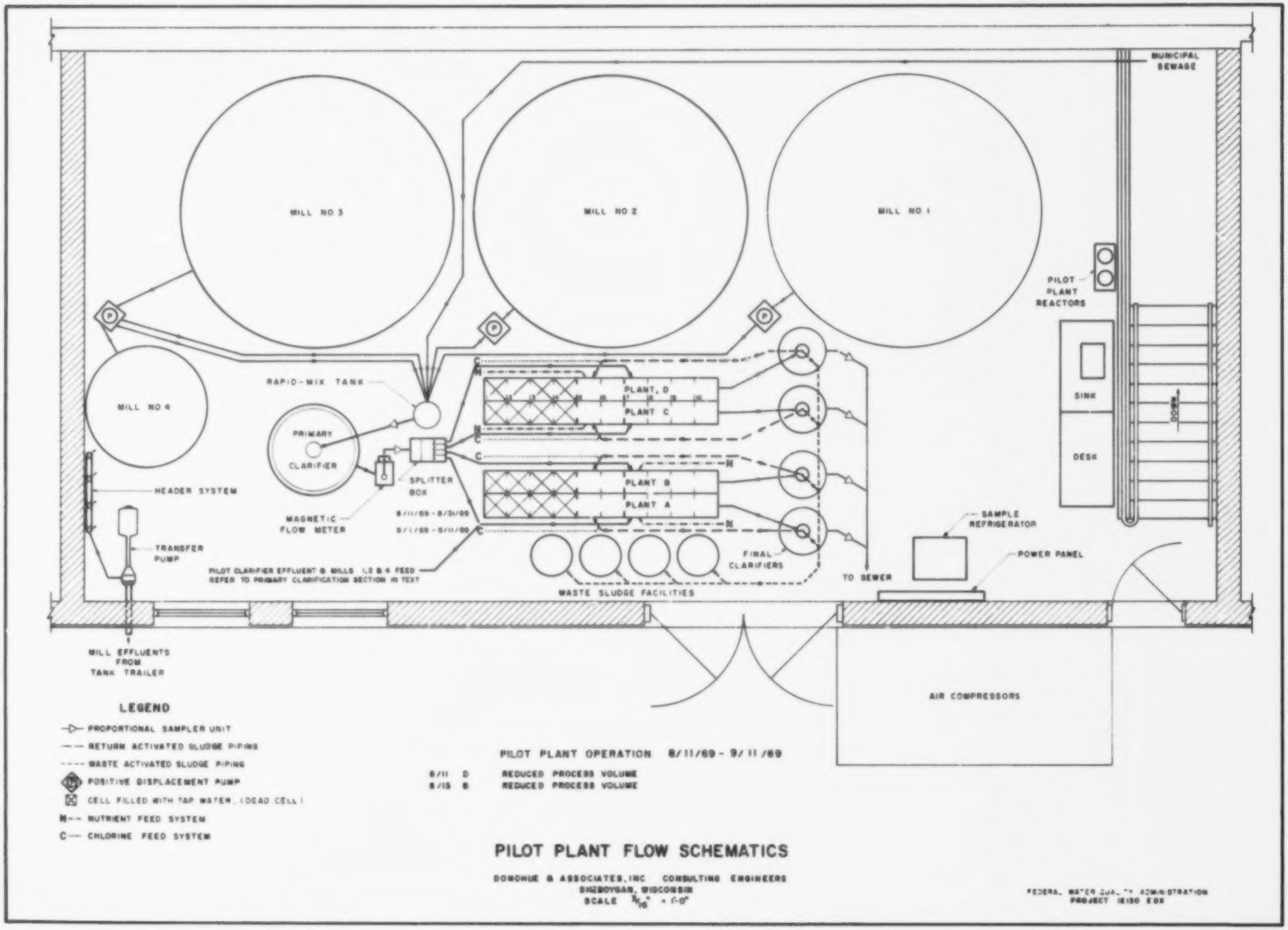
These two plants were operated to provide WAS for the solids handling studies. The oxygen uptake and transfer studies, and sludge production studies were also conducted on these plants.

The pilot plant flow schematics used during Phase IV are illustrated in Figures 42 to 43. The plants were operated according to the theoretical values shown in the following summary.

THEORETICAL PILOT PLANT OPERATION - PHASE IV

September 1 - December 15, 1969

Q Forward, l/d	4310
MLTSS, mg/l	4070
MLVSS, mg/l	3500
RAS-TSS, mg/l	10000
RAS-VSS, mg/l	8600
R/Q	0.69
D_t - Contact, hrs. (R + Q)	2.3
D_t - Reaeration, hrs. (R)	2.8
RAS Chlorination, mg/l	10
Final Clarifier	
D_t (Q) hrs.	3.2
Overflow Rate, gpd/sf	360
Solids Loading, lbs/sf/day	20.8


MUNICIPAL SEWAGE
MILL NO 3
MILL NO 2
MILL NO 1
MILL NO 4
PILOT PLANT REACTORS
RAPID-MIX TANK
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
8/11/69 - 8/31/69
9/1/69 - 9/11/69
HEADER SYSTEM
TRANSFER PUMP
PLANT D
PLANT C
PLANT B
PLANT A
C
N
FINAL CLARIFIERS
WASTE SLUDGE FACILITIES
TO SEWER
SINK
DESK
DOWN
SAMPLE REFRIGERATOR
POWER PANEL
AIR COMPRESSORS
PILOT CLARIFIER EFFLUENT & MILLS 1,2 & 4 FEED
REFER TO PRIMARY CLARIFICATION SECTION IN TEXT
MILL EFFLUENTS FROM TANK TRAILER
LEGEND
PROPORTIONAL SAMPLER UNIT
RETURN ACTIVATED SLUDGE PIPING
WASTE ACTIVATED SLUDGE PIPING
POSITIVE DISPLACEMENT PUMP
CELL FILLED WITH TAP WATER. (DEAD CELL)
N--- NUTRIENT FEED SYSTEM
C--- CHLORINE FEED SYSTEM

PILOT PLANT OPERATION 8/11/69 - 9/11/69

8/11 D REDUCED PROCESS VOLUME
8/15 B REDUCED PROCESS VOLUME

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE 3/16" = 1'-0"

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 42 PAGE 221

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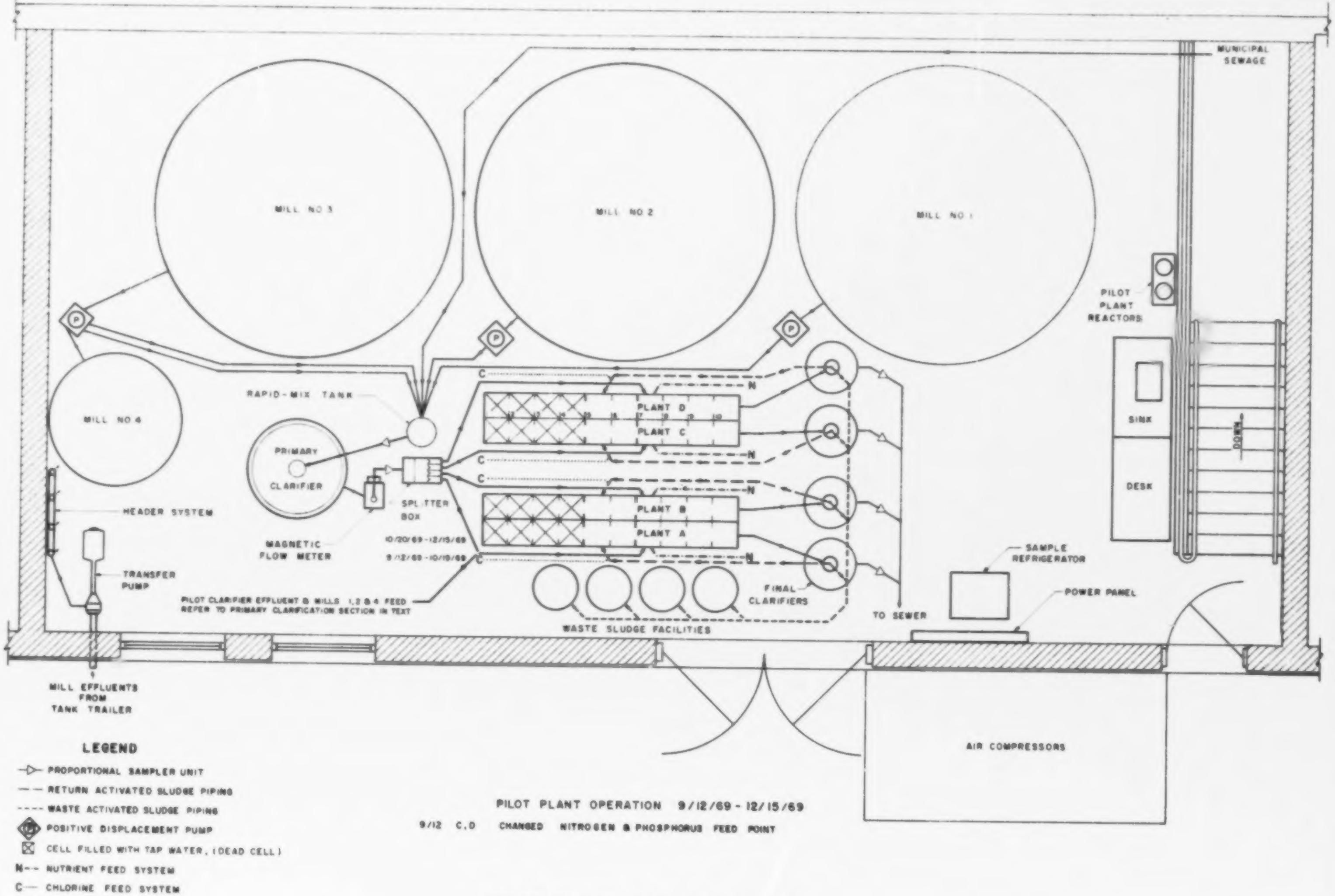
MUNICIPAL SEWAGE
MILL NO 3
MILL NO 2
MILL NO 1
MILL NO 4
PILOT PLANT REACTORS
SINK
DESK
DOWN
RAPID-MIX TANK
PRIMARY CLARIFIER
SPLITTER BOX
MAGNETIC FLOW METER
10/20/69 - 12/15/69
9/12/69 - 10/19/69
PLANT D
PLANT C
PLANT B
PLANT A
C
N
FINAL CLARIFIERS
TO SEWER
SAMPLE REFRIGERATOR
POWER PANEL
WASTE SLUDGE FACILITIES
HEADER SYSTEM
TRANSFER PUMP
PILOT CLARIFIER EFFLUENT & MILLS 1,2 & 4 FEED
REFER TO PRIMARY CLARIFICATION SECTION IN TEXT
MILL EFFLUENTS FROM TANK TRAILER
AIR COMPRESSORS
LEGEND
PROPORTIONAL SAMPLER UNIT
RETURN ACTIVATED SLUDGE PIPING
WASTE ACTIVATED SLUDGE PIPING
POSITIVE DISPLACEMENT PUMP
CELL FILLED WITH TAP WATER, (DEAD CELL)
N--- NUTRIENT FEED SYSTEM
C— CHLORINE FEED SYSTEM
PILOT PLANT OPERATION 9/12/69 - 12/15/69
9/12 C.D CHANGED NITROGEN & PHOSPHORUS FEED POINT

PILOT PLANT FLOW SCHEMATICS

DONOHUE & ASSOCIATES, INC CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN
SCALE $\frac{3}{16}$" = 1'-0"

FEDERAL WATER QUALITY ADMINISTRATION
PROJECT 12130 EDX

FIGURE 43 PAGE 223

Due to the elimination of Mill 3 wastes, the Metro and Mill 1, 2 and 4 flows to Plant A were increased proportionately to provide the same flow quantity as that received by Plants B, C, and D. Between October 3 and 19, (the storm flow studies) the above summary did not apply to Plant A.

Plant B MLVSS was initially set at 4000 mg/l, but was reduced to 3500 mg/l, September 15.

Not shown are the F/M values and BOD:N:P ratios. The F/M value for Plant A was 0.35 and for Plants B, C and D was 0.37. This difference was due to the elimination of Mill 3 feed from Plant A between September 1 and October 19. After that time Plant A also had a theoretical F/M value of 0.37.

The theoretical BOD:N:P ratios were varied during Phase IV as follows:

Date	Plant A	Plant B	Plant C	Plant D
9/1*	100:2.5:0.5	100:5.0:0.5	100:5.0:0.5	100:5.0:0.5
9/11			100:5.0:1.0	100:5.0:1.0
10/21	100:5.0:0.5			
11/24			100:5.0:0.5	
12/9	100:5.0:1.0	100:5.0:1.0	100:5.0:1.0	

*No nitrogen or phosphorus addition was required for Plant A between 9/1 and 10/19 due to elimination of Mill 3 feed. Nitrogen was added to B, C and D and phosphorus was added to C and D. Both nutrients were added to all plants beginning 10/22.

Elimination of Mill 3 Wastes from Feed to Plant A

The elimination of Mill 3 wastes from Plant A and the diverting of Mills 1, 2 and 4 around primary clarification directly to secondary treatment was studied both at average flow (September 1 - October 2) and storm flow (October 3-19) conditions.

The average operating data for September 1-30 are shown in Table 33. Between September 11 and September 15, high BOD and TSS occurred in the effluents of Plants A, C and D, but not in Plant B. This period

AVERAGE PILOT PLANT OPERATING DATA

September, 1969

	Plant A	Plant B	Plant C	Plant D
MLVSS, mg/l	3370	3647	3583	3355
F /M Ratio, BOD/VSS	.29	.33	.31	.36
Aeration Tank Influent				
NH_3 as N, mg/l	22.5	23.7	23.7	23.7
Ortho phosphate as P, mg/l	4.7	3.2	4.7	4.7
BOD:N, 100:	6.2	5.8	5.8	5.8
BOD:P, 100:	1.3	0.8	1.2	1.2
R/Q	0.29	0.44	0.39	0.48
BOD, mg/l				
Unfiltered PE	369	401	401	401
Unfiltered FE	62	35	46	70
Filtered FE	29	16	23	31
% BOD Removal				
Unfiltered FE	83.2	91.3	88.5	82.5
Filtered FE	90.6	95.5	93.5	91.2
TSS in PE, mg/l	138	126	126	126
TSS in FE, mg/l	64	31	58	87
% TSS Removal	53.6	75.4	54.0	31.0
pH of FE	7.6	7.7	7.7	7.7
Settled Sludge Vol. ml	587	426	789	593
SVI	153	101	192	160
RAS-VSS, mg/l	11793	10079	11309	9110
Waste VSS, kg/day	0.6	0.2	0.6	0.2

of poor operation in these three plants was apparently due to insufficient dissolved oxygen in the mixed liquor. During this time Plant B was being operated at a DO of 5 to 6 mg/l whereas the desired DO values in the other three plants were 0.5 to 1 mg/l (September 1-12) and 1-2 mg/l (September 12-19). However, the actual DO values during this period are subject to question due to possible errors in the procedure for DO measurement.

The final effluent BOD and TSS values for Plant A during the days in question were as follows:

DATE	FE-TSS, mg/l	FE-BOD, mg/l
9/11/69	104	147
9/12/69	114	225
9/13/69	86	150
9/14/69	74	134
9/15/69	72	86

If these values are omitted, then the monthly averages for FE-TSS and unfiltered FE-BOD are 59 mg/l and 45 mg/l, respectively (57.2 and 87.8% removals, respectively).

Another parameter of concern when eliminating Mill 3 wastes from Plant A feed was the pH of the combined feed to the aeration tank. The average pH data for various plant streams for September and October, 1969 were as follows:

Period	Plant	pH Values			
1969		Clarifier Influent(a)	Clarifier Effluent(a)	Secondary Influent(b)	Final Effluent
9/1-9/30	A	7.6	7.6	7.0	7.6
	B, C, D	6.8	6.8		7.7
10/1-10/19	A	7.1	7.3	6.9	7.5
	B	6.9	6.9		7.9
	C	"	"		7.7
	D	"	"		7.8
10/20-10/31	A	6.8	6.8		7.7
	B	"	"		7.8
	C	"	"		"
	D	"	"		"

(a) Pilot clarifier data - Plant A and primary clarifier data - Plants B, C, D, 9/1-10/19; primary clarifier data - all plants, 10/20-10/31.

(b) Combination of pilot clarifier effluent plus Mills 1, 2 and 4.

Based on these pH data, there were no apparent pH related problems in the plant operation.

When taking into consideration the minor upset in mid-September, the conclusion was reached that neither the absence of Mill 3 wastes nor the bypassing of Mills 1, 2 and 4 around primary clarification impaired the efficiency of the secondary treatment process.

Storm Flow Studies

The storm flow studies on Plant A were started October 3 by increasing the Metro sewage flow. Between October 7 and October 19 tap water was added to the Metro sewage to reduce the BOD to approximately 100 mg/l. The full compliment of tap water was reached October 8 and the study was continued through October 19. (See the report section entitled "Primary Clarification" for details on pilot clarifier operation.)

The storm flow data for Plant A are presented in two sections, October 1-19 and October 20-31, in Table 34. During the high flow operation the pilot plant was not upset, although there was a decrease in overall plant performance with regard to TSS and BOD removals. This poor performance is attributed to the inability of the final clarifier to maintain good suspended solids removals under the high flow conditions. Note that according to the SVI data, the settling characteristics of the biological floc did not change significantly. Also the filtered final effluent BOD's (listed below) did not indicate any significant reduction in biological treatment efficiency due to the high hydraulic loadings.

Plant A Filtered Final Effluent BOD

10/1	19 mg/l
10/8	16 mg/l
10/16	14 mg/l
10/23	17 mg/l
10/30	23 mg/l

Special Laboratory Studies

Special studies conducted on Plants C and D during Phase IV, in addition to the normal laboratory routine, were as follows:

1. Oxygen uptake
2. Oxygen transfer
3. Sludge production

PLANT A OPERATING DATA

Item	October 1-19			October 20-31		
Forward Flow	172% of Average Range - 101% - 278%			Average		
	Min.	Avg.	Max.	Min.	Avg.	Max.
MLVSS, mg/l	2784	3588	4500	2900	3780	4472
F/M (BOD/VSS)	0.17	0.37	0.55	0.23	0.29	0.34
SVI	56	69	83	47	57	64
Final Clarifier						
D_t, hrs.	1.2	1.9	3.2	2.5	3.1	3.9
Solids loading, lbs/sq ft/day	15	27	42	14	18	23
Overflow rate, gpd/sf	366	624	1009	296	377	460
PE TSS, mg/l	50	124	372	76	136	180
FE TSS, mg/l	19	70	138	20	43	62
% Removal		44%			68%	
PE BOD, mg/l	150	312	476	358	441	530
FE BOD, mg/l	34	64	143	30	46	72
% Removal		80%			90%	

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The data obtained during the special studies are presented in Table 35. With the exception that the oxygen uptake studies were conducted on grab samples from the particular aeration section being studied, the procedures utilized and the data presented are the same as described in the special studies section of Phase III.

Final effluent chlorination was also studied and is discussed in the report section entitled, "Final Effluent Chlorination."

Summary of Pilot Plant Operation During Phase IV

The results of the special studies on Plant A were as follows:

1. The elimination of Mill 3 effluent from the composite feed to the plant and the bypassing of Mills 1, 2 and 4 around primary clarification did not adversely affect the performance of the plant.

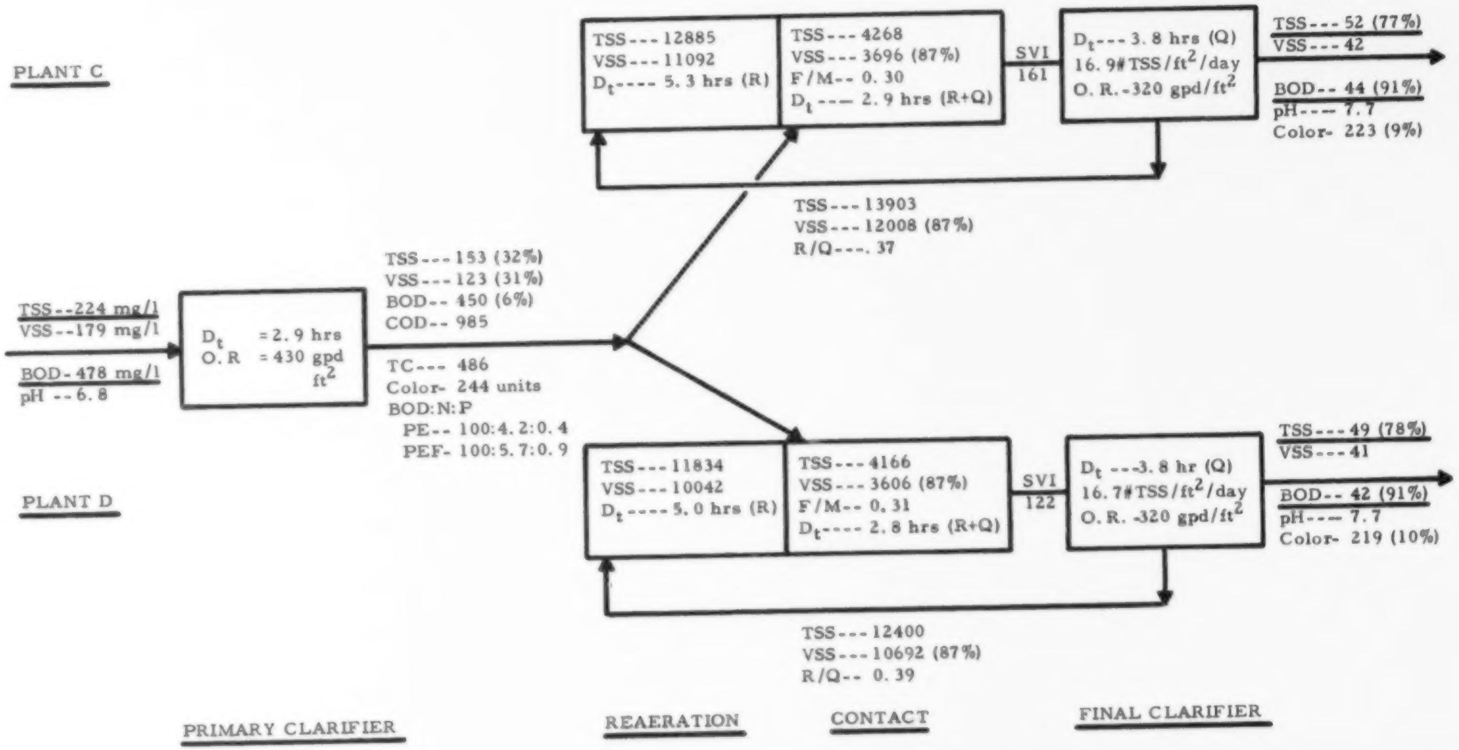
2. Operating the unit at a hydraulic flow averaging 172% of the normal daily flow for 2 1/2 weeks did not adversely affect the biological treatment efficiency of the plant. However, it did cause poorer TSS removals in the final clarifier which resulted in decreased TSS and BOD removal efficiencies across the secondary unit.

Plants C and D were operated under constant conditions to produce waste sludges for the solids handling studies and to permit some additional special studies. Average operating data for Plant C and D between August 1 and December 15, 1969 are illustrated in Figure 44. These plants achieved overall removals of 91% and 78%, respectively, for BOD and TSS. A higher degree of TSS removal would be expected for a large-scale treatment plant due to increased final clarifier efficiency.

The relationship between RAS chlorination and filament concentration for the four units is illustrated in Figure 45. (See Phase I for nomenclature on Figure 45.) The average, maximum and minimum laboratory data for each month during Phase IV are presented in Appendix D.

SPECIAL LABORATORY STUDIES - PHASE IV

	PLANT C						PLANT D					
O_2 UPTAKE	9/8/69	9/23	10/8-9	10/22	11/19		9/8		10/8-9	10/22	11/19	
REAERATION ZONE												
Effective D. T., hr.	2.56	2.84	3.44	2.72	4.88		2.40		3.32	2.92	4.80	
MLVSS, mg/l	8840	10792	10588	12416	11748		8924		9236	11660	11592	
Uptake Rate, mg/l/hr.	59; 48	108; 96	81; 80	84; 81	93; 84		60; 48		72; 57	77; 71	75; 72	
CONTACT ZONE												
Total D. T., hr.	2.56	2.84	3.44	2.72	4.88		2.40		3.32	2.92	4.80	
MLVSS, mg/l	4736	3230	4012	4220	3096		3368		3708	3604	3544	
Uptake Rate, mg/l/hr.	78; 36	73; 36	74; 42	90; 44	72; 42		75; 39		72; 39	114; 36	83; 36	
BOD conc., mg/l	340; 29	209; 23	56; 25	246; 9	319; 22		102; 42		51; 14	116; 21	46; 18	
Lbs. O_2 Required / Lb. BOD Removed	.70	2.02	1.45	.94	1.59		.70		1.23	.95	1.34	
O_2 TRANSFER	9/8/69		10/8-9	10/22	11/19		9/8		10/8-9	10/22	11/19	
REAERATION ZONE												
Alpha (α)	.32; .53		.62; .77	.57; .86	.94; .95		.49; .89		.96; .80	.64; .63	.92; .64	
Beta (β)	.91; .92		.77; .74	.87; .83	.85; .86		.96; .92		.81; .84	.86; .90	.80; .85	
CONTACT ZONE												
Alpha (α)	.68; .56		.80; .89	.69; .77	.86; 1.19		.67; .64		.67; .68	.49; .85	.81; 1.01	
Beta (β)	.96; 1.03		.87; .95	.90; .91	.72; .90		.95; 1.00		.84; .92	.95; .99	.76; .87	
SOLIDS PRODUCTION	9/1-15	9/15-30	9/30-10/15	10/15-11/15	11/5-12/1	12/1-15	9/1-15	9/15-30	9/30-10/15	10/15-11/5	11/5-12/1	12/1-15
Lbs. TSS Produced / Lb. BOD Removed	0.64	0.42	0.53	0.70	0.63	0.78	0.32	0.43	0.50	0.51	0.55	0.57


PLANT C
PLANT D
TSS--224 mg/l
VSS--179 mg/l
BOD-478 mg/l
pH --6.8
D$_t$ =2.9 hrs
O.R =430 gpd/ft^2
TSS---153 (32%)
VSS---123 (31%)
BOD--450 (6%)
COD--985
TC---486
Color- 244 units
BOD:N:P
PE-- 100:4.2:0.4
PEF- 100:5.7:0.9
TSS---12885
VSS---11092
D$_t$---- 5.3 hrs (R)
TSS---4268
VSS---3696 (87%)
F/M-- 0.30
D$_t$--- 2.9 hrs (R+Q)
SVI
161
D$_t$---3.8 hrs (Q)
16.9#TSS/ft^2/day
O.R.-320 gpd/ft^2
TSS---52 (77%)
VSS---42
BOD--44 (91%)
pH---7.7
Color- 223 (9%)
TSS---13903
VSS---12008 (87%)
R/Q---.37
TSS---11834
VSS---10042
D$_t$----5.0 hrs (R)
TSS---4166
VSS---3606 (87%)
F/M-- 0.31
D$_t$---- 2.8 hrs (R+Q)
SVI
122
D$_t$ --3.8 hr (Q)
16.7#TSS/ft^2/day
O.R. -320 gpd/ft^2
TSS---49 (78%)
VSS---41
BOD--42 (91%)
pH---7.7
Color- 219 (10%)
TSS---12400
VSS---10692 (87%)
R/Q-- 0.39
PRIMARY CLARIFIER
REAERATION
CONTACT
FINAL CLARIFIER

AVERAGE PILOT PLANT OPERATION - AUGUST 1, 1969 TO DECEMBER 15, 1969

FIGURE 44 PAGE 233

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PILOT PLANT OPERATION - PHASE IV - 8/1/69 TO 12/15/69

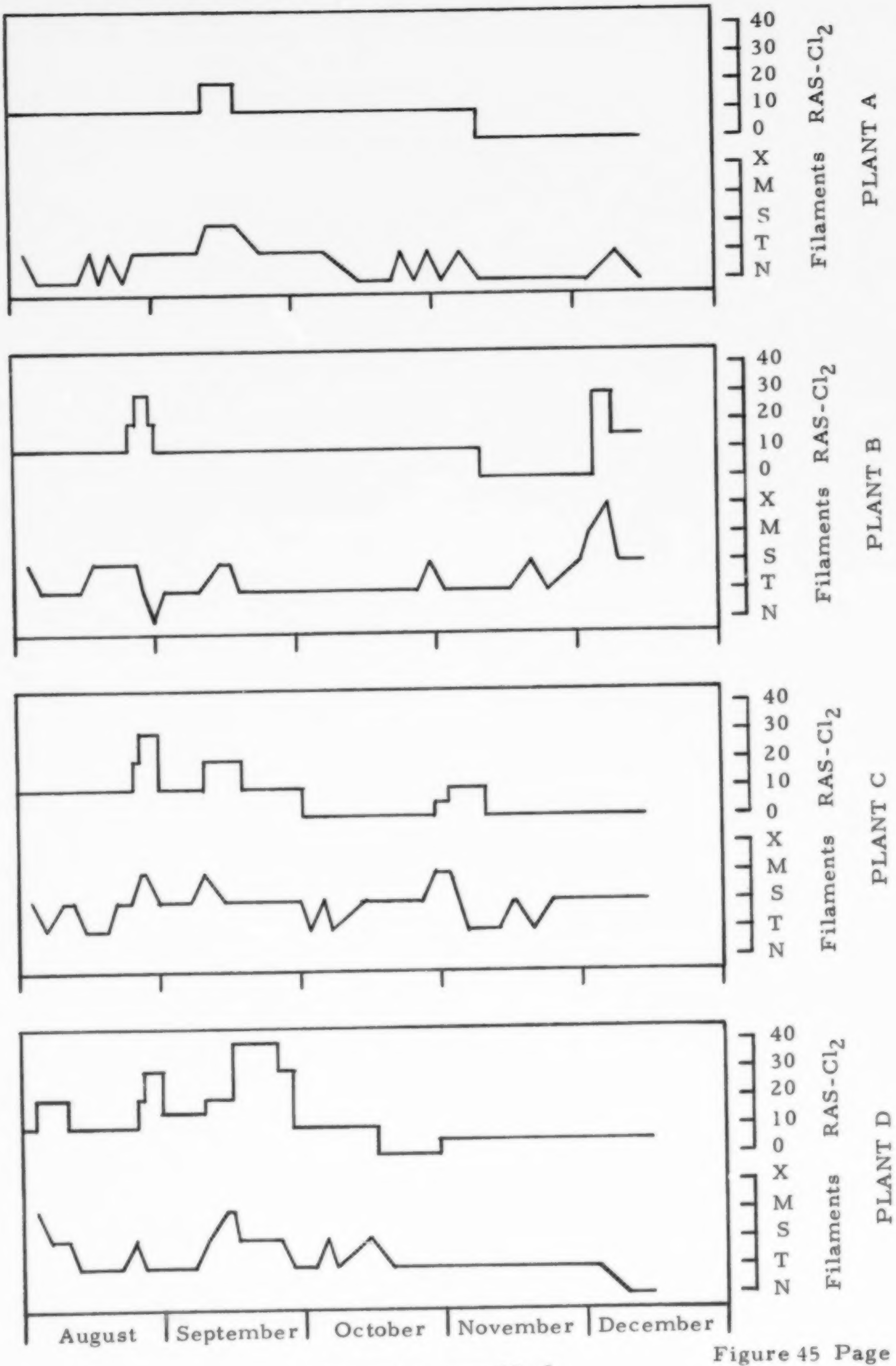

Figure 45 Page 235

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COST ESTIMATES FOR JOINT TREATMENT AND SEPARATE TREATMENT FACILITIES

The pilot plants were operated through December 15, 1969. The laboratory information obtained on the pilot plant operation and special studies between July 17 and December 15, with the exception of the solids-handling unit process data, was utilized for development of full-scale design parameters. A summary of the more important design parameters is presented in Table 36. (See Appendix F for a complete summary of the theoretical design parameters. Note that the BOD and TSS loads to the secondary unit do not include any allowance for return sidestreams from the solids handling unit processes.)

These revised parameters were then utilized for preparation of cost estimates for a full-scale contact stabilization plant. Information relative to the solids-handling unit process studies was sent to each manufacturer who then submitted flow schematics, operating parameters, and cost estimates. Since the solids handling unit process schematic was not finalized at that time, an averaged cost, based upon seven possible flow schematics developed from the individual cost and performance estimates presented by the participating manufacturers, was used in the final cost estimate. (See Appendix F for the flow, BOD and TSS quantities, and design scale-up factors used in the cost estimates.)

These capital and operating cost estimates were utilized by Black & Veatch Consulting Engineers to prepare a cost distribution report for the GBMSD.(19) The main parameters utilized to develop the cost distribution were:

Average Flow Rate, MGD
Peak Flow Rate, MGD
BOD, Tons/Day
TSS, Tons/Day

The cost distributions for the joint treatment concept for each Mill and GBMSD were developed from the Black & Veatch report, (see Table 37). The costs for the separate treatment concept for GBMSD were also developed from this report. The remaining values shown in the Table were either obtained from the Mills or estimated by the project staff.

Note that under capital investment costs listed in Table 37 is included an allowance for operating contingency reserve and normal annual capital improvements. To maintain a utility in a sound financial position, it is necessary to provide a contingency reserve to insure that

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FULL-SCALE DESIGN PARAMETERS
FOR
CONTACT STABILIZATION TREATMENT PLANT

Primary Clarification (Metro Only)

Average Flow	30.0 MGD
Peak Flow	120.0 MGD
Detention Time	2.7 Hours
BOD Removal	33.0 %
TSS Removal	60.0 %
Primary Sludge	60,300 GPD; 5.5% TSS, 83.7 % Volatile

Secondary Treatment

Average Forward Flow (Q)	53.9 MGD
Peak Forward Flow (Q)	94.0 MGD
BOD (470 mg/l)	106.1 Tons/Day
TSS (110 mg/l)	25.3 Tons/Day
Mixed Liquor VSS (86% Volatile)	3500 mg/l
Lbs. BOD Applied/lb. MLVSS Under Aeration	0.3
Detention Time	
Reaeration (R)	4.1 Hours
Contact (R + Q)	2.9 Hours
R/Q	0.7
Lbs. O_2 Required/lb. BOD Removed @ 26.6° C	1.6

Waste Activated Sludge

Lbs. TSS Produced/lb. BOD Removed	0.65
Volume	1.6 MGD
TSS Concentration	1.0 %

Final Clarification

Solids Loading, lb. TSS/ft^2/day	23

Overall Efficiency

BOD Removal	Exceed 90%
TSS Removal	Exceed 90%

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DISTRIBUTION OF CAPITAL AND OPERATING COSTS

	Mill 1	Mill 2	Mill 3	Mill 4	GBMSD	Total
Average Flow, MGD	5.0	5.0	13.25	0.6	30.0	53.85
Peak Flow, MGD	6.3	6.3	16.5	0.7	120.0	143.8
BOD, Tons/Day	30.0	15.0	33.2	7.0	29.5	114.7
TSS, Tons/Day	5.0	2.0	6.6	2.5	23.0	39.1
Joint Treatment Concept						
Estimated Share of Capital Cost (a)	$5,501,000	$2,995,000	$7,034,000	$1,328,000	$14,269,000	$31,127,000
Estimated Share of Operation and Maintenance Costs (b)	$ 643,000	$ 373,000	$ 887,000	$ 147,000	$ 1,037,000	$ 3,087,000
Capital Investment Costs (e)	$ 658,000	$ 356,000	$ 838,000	$ 158,000	$ 1,695,000	$ 3,705,000
Estimated Total Annual Costs	$1,301,000	$ 729,000	$1,725,000	$ 305,000	$ 2,732,000	$ 6,792,000
Separate Treatment Concept						
Estimated Capital Costs (a) (c)	$8,500,000	$6,000,000	$3,000,000	$1,600,000	$18,696,000	$37,796,000
Estimated Operation and Maintenance Costs (b) (d)	$1,112,000	$ 645,000	$1,005,000	$ 391,000	$ 1,343,000	$ 4,496,000
Capital Investment Costs (d)(e)	$1,011,000	$ 714,000	$ 357,000	$ 190,000	$ 2,224,000	$ 4,496,000
Estimated Total Annual Costs	$2,123,000	$1,359,000	$1,362,000	$ 581,000	$ 3,567,000	$ 8,992,000

a. Estimated total capital costs (including allowance for administration, engineering, contingencies and inflation during construction) at completion of construction -- 9/30/72

b. Estimated operating and maintenance costs for fiscal year ending 3/31/75

c. Mill 1 estimate made by project staff, Mills 2, 3 and 4 estimates obtained from respective mills

d. Mills 1 - 4 estimates made by Project Staff

e. Includes contingency reserve, normal capital improvements, and debt service retirement (20 yrs. -7%)

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funds will be available to meet fluctuations in operating costs. The allocation for normal annual capital improvements would be utilized for improvements and additions to the system above the normal maintenance items.

Based upon this final cost estimate, the joint treatment venture would require an estimated capital expenditure of $31,127,000, $3,087,000 in annual operating costs and $6,792,000 in total annual costs. If each of the participants were to construct their own facilities, the estimated capital costs would be $37,796,000, annual operating costs would be $4,496,000, and total annual costs would be $8,992,000. Therefore, the joint venture would result in an accrued savings of approximately $6,669,000 in capital costs, $791,000 in annual operating costs, and $2,200,000 in total annual costs.

The percentage distribution of the estimated construction costs is shown in Table 38. Note that the aeration equipment and basins, and solids handling facilities make up an estimated 51% of the total construction cost.

The Mills evaluated the factors involved in becoming a part of this joint venture and gave their decision to the GBMSD on July 1, 1970. Mills 1 and 2 will become participants in the joint venture; Mills 3 and 4 elected to provide their own facilities to treat their wastes.

DISTRIBUTION OF ESTIMATED TREATMENT PLANT CONSTRUCTION COSTS

Item	Percent of Total Construction Cost*
Influent Pumping Facilities	10.9
Screening and Grit Removal	3.0
Primary Clarification (Metro Only)	3.9
Aeration Equipment and Basins	18.9
Return Activated Sludge Facilities	2.1
Final Clarification	9.1
Chemical Feeding Facilities	3.3
Solids Handling Facilities	32.2
Electrical and Instrumentation	7.4
Sitework	7.2
Administration and Control Buildings	2.0
	100.0

* Administration, engineering and contingencies are not included.

SOLIDS HANDLING UNIT PROCESS STUDIES

An extensive solids handling unit process study was conducted between September and December, 1969. The unit processes studied were:

Centrifugation
Dissolved air flotation
Gravity thickening
Heat treatment
Low pressure oxidation
Pressure filtration
Vacuum filtration

A summary of the unit processes which were analyzed, test equipment which was used and the manufacturers participating in the studies is presented in Table 39. The testing schedule which was followed is shown in Figure 46. The tests related to each unit process being studied were conducted in accordance with the procedures developed by the respective manufacturers.

The objectives of this study were as follows:

1. Provide each participating manufacturer with the necessary laboratory data required to prepare accurate unit process performance and cost estimates.

2. Determine the characteristics of sidestreams from the solids handling unit processes which would be returned to the secondary treatment system.

3. Evaluate the applicability of each unit process to this particular combination of waste sludges.

The laboratory analyses conducted on the samples from each unit process study are summarized in Table 40. (The laboratory data obtained from these studies are presented in Appendix E. Chemical aids were used in some of the studies conducted; those unit processes and tests in which chemicals were used are listed in this Appendix.)

A summary of the minimum and maximum total suspended solids and BOD values obtained during the unit process studies is presented in Table 41. It is important to note that these data are for a sludge which is primarily waste activated in nature. The approximate volume ratio for the composite sludge samples analyzed was 13 parts of waste activated sludge to 1 part of primary clarifier sludge. This composition was used for all tests except the dissolved air flotation tests by Rex Chainbelt, Inc. and the Eimco Corporation, and the gravity thickening and filter leaf

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SOLIDS HANDLING PROCESS STUDIES

Unit Process	Company	Test Site*	Equipment Utilized
Centrifugation	Sharples Equipment Division		Sharples Solid Bowl Unit, Fletcher Basket Unit
Dissolved Air Flotation	Rex Chainbelt, Inc.		Bench Scale Pressure Cylinder Unit
	The Eimco Corp.	Salt Lake City, Utah	Manufacturer's Batch Equipment (a)
Gravity Thickening	Dorr Oliver, Inc.		1-liter stirred cylinder
	The Eimco Corp.		1-liter stirred cylinder
	Walker Process Equipment		3-1/2" dia. x 12' SWD cylinder, 7-1/2" dia. x 14' SWD cylinder, 1-liter cylinder (all units had stirrers).
Heat Treatment	BSP Corporation	Colorado Springs, Colo.	Manufacturer's Batch Equipment (b)
	Dorr Oliver, Inc.	Stamford, Conn.	(c)
	Zimpro, Inc.	Rothschild, Wis.	(d)
Low Pressure Oxidation	Zimpro, Inc.	Rothschild, Wis.	(d)
Pressure Filtration	Beloit-Passavant Corporation		Portable "Bomb" Pressure Filter Unit
Vacuum Filtration	The Eimco Corp.		Filter Leaf Apparatus
	Walker Process Equip.		Filter Leaf Apparatus
FEMicroscreening	Beloit Passavant Corp.		Modified Filter Leaf App.
	Crane-Glenfield, Inc.		Field Test Kit
	Southwestern Engr. Co.		18" Production Unit

(a) A 10-gallon sample was analyzed.
(b) A 15-gallon and a 20-gallon sample were analyzed.
(c) A 5-gallon and a 10-liter sample were analyzed.
(d) A total of two 150-gallon samples were analyzed in the two processes.

* All tests conducted at Green Bay except as noted.

SPECIAL STUDIES SCHEDULE - PHASE IV - 1969

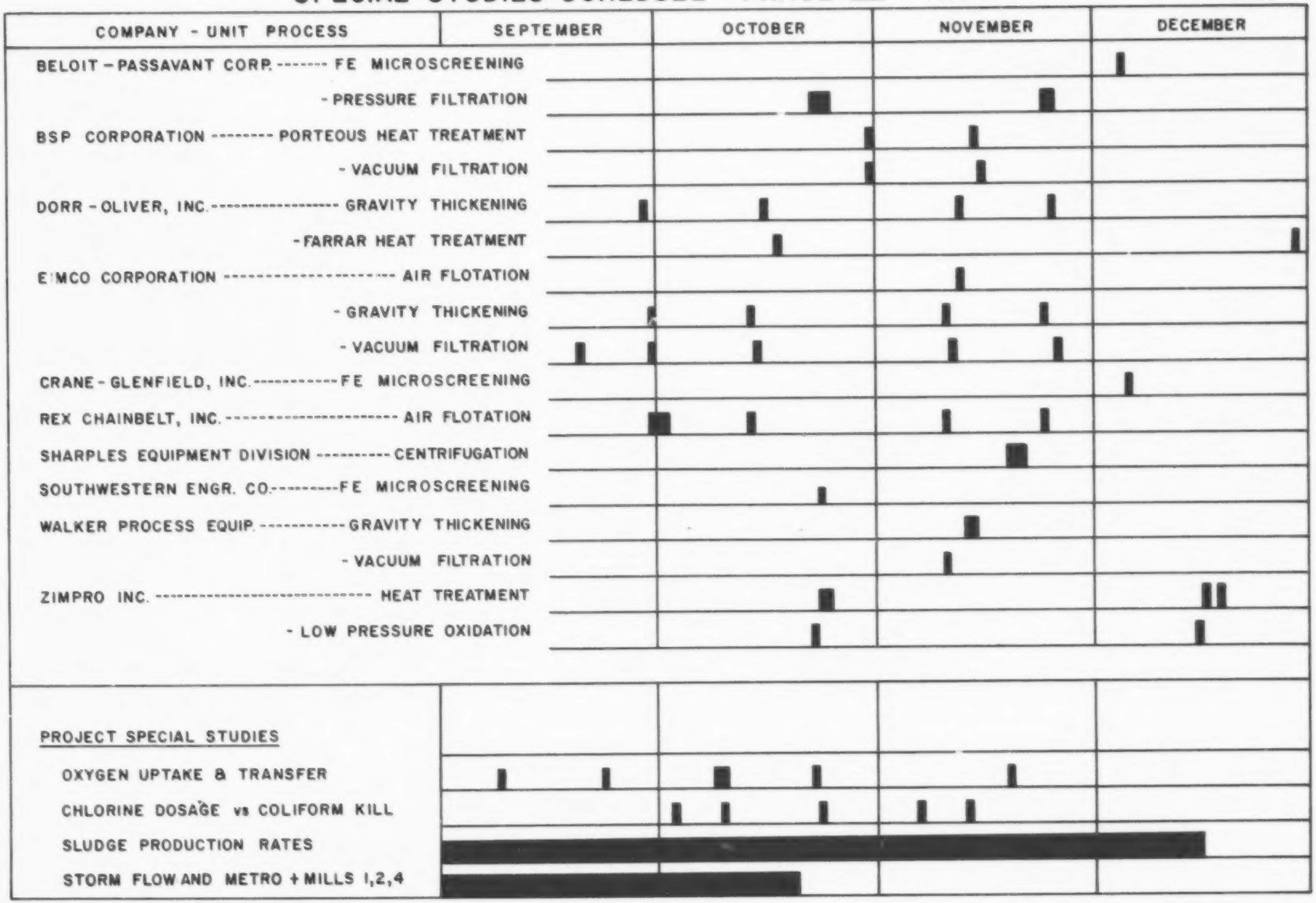

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FIGURE 46 PAGE 249

SAMPLE ANALYSES SCHEDULE

Unit Process	Footnote	Sample Source	Solids Analysis				pH	BOD	Nutrient Analysis			% Moist
			TS	TVS	TSS	VSS			NH_3	O.P.	T.P.	
Thickening	a, b, c	Raw Feed Sludge			x	x	x		x	x	x	
	c	Supernatant			x	x	x	x	x	x	x	
	b	Pressurized Flow			x	x	x	x	x	x	x	
	b	Combined Flow			x	x	x					
	b	Subnatant			x	x	x	x	x	x	x	
	a	Centrate			x	x	x	x	x	x	x	
	a	Cake	x	x								x
Conditioning	d	Raw Feed Sludge			x	x	x		x	x	x	
	d	Decant			x	x	x	x	x	x	x	
	d	Decant Sludge			x	x	x					
Dewatering	a, e, f	Feed Sludge			x	x	x		x	x	x	
	a	Centrate			x	x	x	x	x	x	x	
	e, f	Filtrate			x	x	x	x	x	x	x	
	a, e, f	Cake	x	x								x
FE Microscreening	---	Raw Final Effluent			x	x	x	x	x	x	x	
	---	Filtrate			x	x	x	x	x	x	x	

a. Centrifugation
b. Dissolved Air Flotation
c. Gravity Thickening
d. Heat Treatment and Low Pressure Oxidation
e. Pressure Filtration
f. Vacuum Filtration

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SOLIDS HANDLING UNIT PROCESS STUDIES

Minimum and Maximum Data*

Sample Source (Data is as mg/l except as indicated)	TSS Min.	TSS Max.	BOD Min.	BOD Max.
Gravity Thickening				
Feed Sludge	2676	16864		
Supernatant	84	313	60	335
Thickened Sludge	3.0%	4.2%		
Dissolved Air Flotation				
Feed Sludge	10044	12364		
Subnatant	104	320	255	589
Float Concentration	1.7%	6.9%		
Centrifigation				
Solid Bowl				
Feed Sludge	29708	30148		
Centrate	330	2200	1170	1875
Cake (TS)	8.1%	11.0%		
Basket				
Feed Sludge	14888	17956		
Centrate	904	2492	338	975
Skimmed Cake (TS)	6.2%	9.8%		
Bowl Cake (TS)	10.2%	13.8%		
Heat Treatment				
Feed Sludge	29392	34416		
Cooked Sludge	7400	19920	7000	8520
Decant	106	300	4000	13200
Decant Sludge	4.19%	7.75%		
Filtrate	266	1970	4300	7500
Cake (TS)	25.0%	38.0%		
Low Pressure Oxidation				
Feed Sludge	29994	30588		
Cooked Sludge	10400	11400		
Decant	200	-----	5700	6000
Decant Sludge	5.83%	6.78%		
Filtrate	350	730	5600	5700
Cake (TS)	31.7%	33.4%		
Vacuum Filtration				
Feed Sludge	22280	36680		
Filtrate	124	1240	870	1575
Cake (TS)	11.4%	19.0%		
Pressure Filtration				
Raw Feed Sludge	28688	34304		
Filtrate	7	73	600	2310
Cake (TS)	29.4%	51.1%		

* All values mg/l except as noted

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tests by Walker Process Equipment. In these latter tests the samples analyzed were straight WAS.

Summary of the Solids Handling Unit Process Studies

Based upon the data obtained during the solids handling studies on this particular combination of sludges, the following general conclusions were made:

1. Gravity thickening of the composite sludge is not economically feasible.
2. Thickening of the waste activated sludge by air flotation was not enhanced by using flotation aids.
3. Large coagulant dosages would be required to utilize centrifuges for thickening the composite sludge.
4. Conditioning of the composite sludge by chemicals prior to dewatering is not economically feasible.
5. Conditioning of the sludge by the heat treatment and low pressure oxidation systems resulted in significant BOD and nutrient concentrations in the sidestreams from these processes.
6. Conditioning of sludge by use of ash required a higher than expected ash to solids ratio.

Sidestreams from solids handling unit processes have usually been ignored in the past when the applicability of a unit process to a particular solids handling problem was being analyzed. In this study, many tests were conducted to characterize the individual sidestreams from each process. It was found that there were considerable variations in the characteristics of the sidestreams, (BOD, suspended solids, and nutrient content), which could significantly alter the design of the secondary system and the unit process under consideration. Since these sidestreams can be both a benefit (source of nutrients for a nutrient-deficient waste) and a detriment (added BOD and TSS load on treatment units), it is necessary to know the characteristics of the sidestreams to select the most efficient and economical sludge handling schematic.

In addition to these studies, thickening of the waste activated sludge by returning it to the primary clarifier was also investigated. See the section entitled "Primary Clarification".

Estimates of capital costs were obtained from the respective manufacturers and were utilized in the final cost estimates. Based on the data supplied a sludge handling capital cost of approximately $10,000,000 (including allowance for administration, engineering, contingencies and inflation during construction) was utilized. Further analyses of costs for alternative sludge handling processes is beyond the scope of this report. A more comprehensive study will be made during final plant design.

BTU VALUE OF SLUDGES

Two sets of eleven sludge composite samples were sent to an outside laboratory for Btu determinations.

The daily grab samples were dried at 105°C and composited with previously dried samples. Approximately 25 grams of each sample were sent to the testing laboratory where the Btu analyses were conducted according to Manual #130, Bomb Calorimetry, published by the Parr Instrument Company. Volatile solids analyses were conducted on the second set of samples in the GBMSD laboratory.

The sample compositions were as follows:

Sample Number	Composition
1 - 4	Grab sample of primary clarifier sludge mixed with a grab sample of WAS in volume ratio of 1:6 (primary sludge to WAS).
5	Grab sample of pilot clarifier sludge (which contained WAS).
6	Grab sample of pilot clarifier sludge (which contained WAS) mixed with digested pilot clarifier sludge (Digester No. 2) in volume ratio of 1:3 (pilot clarifier sludge to digested sludge).
7 - 10	Grab sample of WAS.
11	Grab sample of primary clarifier sludge.

The results of the tests on samples composited between May 1-15 and May 16-31, 1969 are shown in Table 42. The Btu value of 9600 Btu per pound of TVS was assumed for sludge cake going to an incinerator when developing the final cost estimates. This was based on the average of 9679 Btu/lb of TVS for the two sets of primary clarifier sludge plus WAS samples.

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BTU VALUE OF SLUDGES

Sample Number	Sample Description	May 1-15, 1969 BTU/lb TS	May 1-15, 1969 BTU/lb TVS*	May 16-31, 1969 % Volatile	May 16-31, 1969 BTU/lb TS	May 16-31, 1969 BTU/lb TVS
1	CS-V Primary Clarifier Sludge plus WAS	7732	9487	81.5	7893	9685
2	CS-C Primary Clarifier Sludge plus WAS	7857	9664	81.3	7893	9708
3	K-V Primary Clarifier Sludge plus WAS	7514	9323	80.6	7929	9837
4	K-C Primary Clarifier Sludge plus WAS	7532	9769	77.1	7676	9956
5	K-C Pilot Clarifier Sludge (including WAS)	8235	10807	76.2	7803	10240
6	K-C Pilot Clarifier Sludge (including WAS) plus Digested Sludge	7496	10678	70.2	7586	10806
7	CS-V WAS	7821	10053	77.8	7676	9866
8	CS-C WAS	7911	10368	76.3	7694	10084
9	K-V WAS	7911	10261	77.1	8145	10564
10	K-C WAS	7514	10237	73.4	7676	10458
11	Primary Clarifier Sludge	7550	8977	84.1	7730	9191

* Estimates based on % Volatile values for samples collected May 16-31.

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OXIDATION OF SULFIDES IN PRIMARY CLARIFIER EFFLUENT

Sulfide Oxidation By Chlorine Addition

Studies on chlorine addition to pilot plant primary effluent (PP-PE) were made on November 11 and December 19, 1968. The objective was to determine the quantity of chlorine necessary to reduce the total sulfide concentration to a negligible amount and thus control the growth of filamentous sulfur bacteria.

One milliliter of household bleach was diluted to 1000 mls with distilled water and this solution (A) was added to 100 mls of pilot plant primary effluent. The equipment used was a Beckman Zeromatic II pH meter, an Orion Sulfide Electrode Model 94-16, a single junction reference electrode and a Magnastirrer.

The pH of the sample was measured before the first and after the last addition of solution A to the sample. The pH of the PP-PE was 6.55 in each case; therefore a constant pH was assumed during the test. Since the testing required approximately one hour, there was the possibility of sulfide oxidation due to surface aeration of the sample. Therefore, a control sample was set up and tested; 100 mls of PP-PE was stirred for one hour at a similar rate as the test sample. There was no appreciable decrease in sulfide concentration due to the stirring. Therefore, any change in sulfide concentration in the original sample was assumed to be due to the addition of chlorine.

A graph of chlorine dosage versus total sulfide concentration is shown in Figure 47. The graph shows that a dosage of 20-25 mg/l of chlorine is required to reduce the sulfide content in the primary clarifier effluent to an insignificant amount.

Sulfide Oxidation By Preaeration

Tests to determine the effectiveness of preaeration as a method of reducing the total sulfide concentration were conducted January 17, 1969.

The test conditions were as follows: (Air was used as an oxygen source.)

Sample	Volume Liters	Time of Aeration Hours	pH Initial	pH Final	Dissolved Oxygen mg/l
A	3	1-1/2	6.70	7.05	4.0±
B	3	2	6.75	7.95	8.0±

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PRIMARY EFFLUENT TOTAL SULFIDE CONTENT

versus

CHLORINE DOSAGE

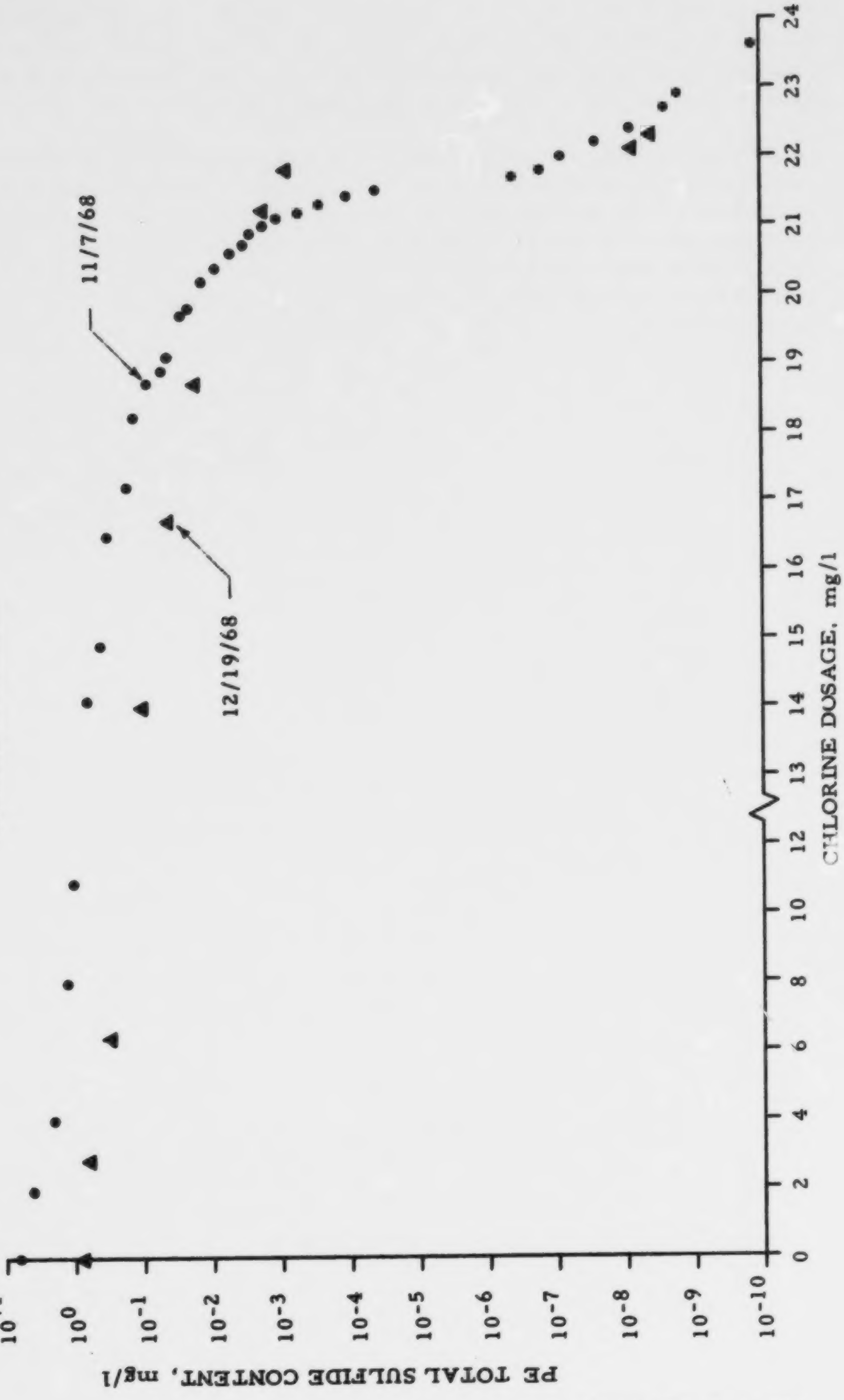

Figure 47 Page 263

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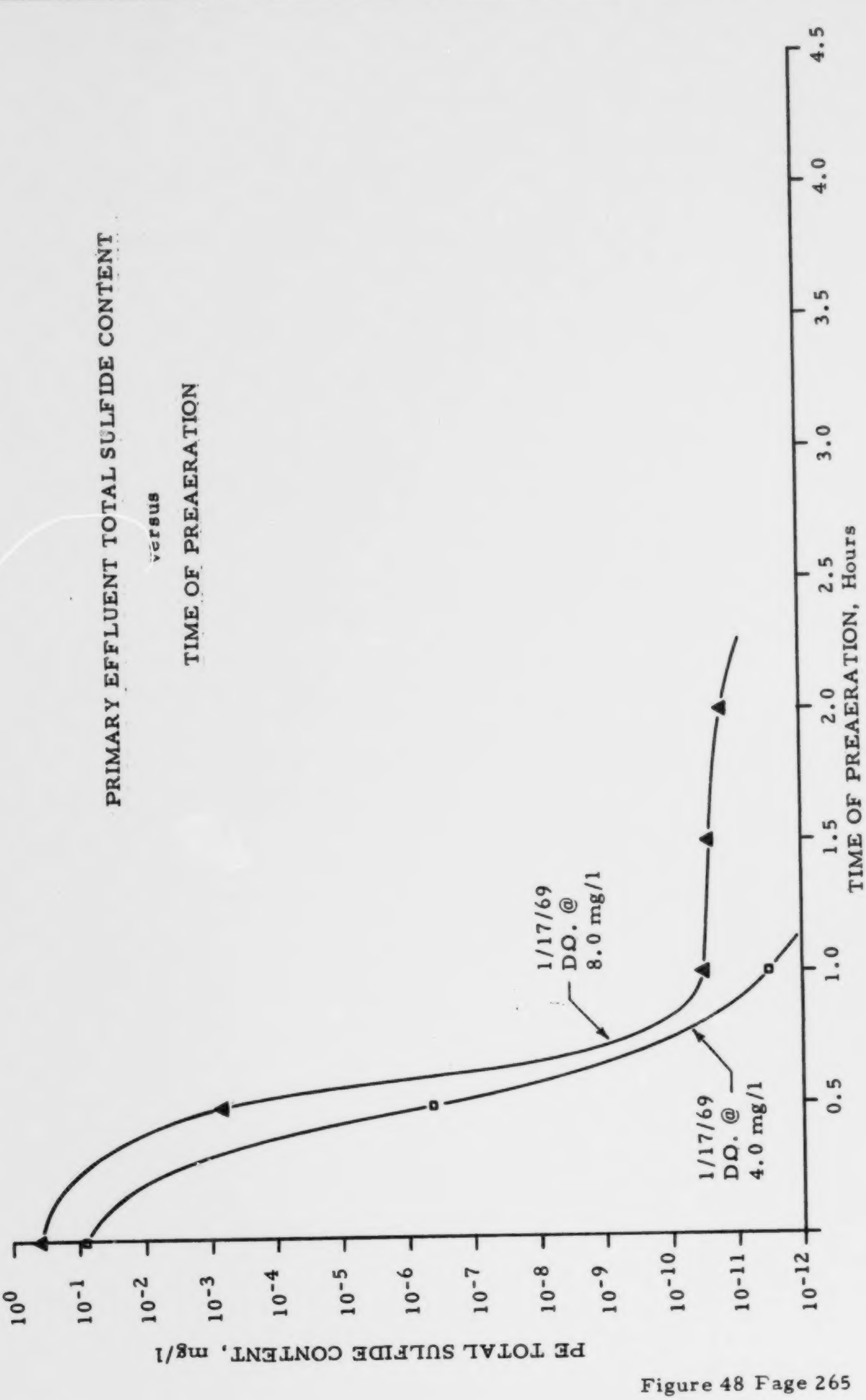
The results of this study are presented in Figure 48. Based on these curves it would require approximately 30 - 45 minutes to reduce the total sulfide content to a negligible amount. The higher dissolved oxygen content did not appear to be beneficial in this test.

In summary, both pre-chlorination and pre-aeration were effective in reducing the total sulfide content. An economic comparison plus evaluation of the detriment or benefit of the two methods of sulfide oxidation would be required to determine the best procedure. However, in this particular research project it was later determined that RAS-chlorination was much more effective for controlling the filamentous sulfur bacteria.



PRIMARY EFFLUENT TOTAL SULFIDE CONTENT

versus

TIME OF PREAERATION

Figure 48 Page 265

FINAL EFFLUENT CHLORINATION

Chlorine dosage versus chlorine residual studies were made on the final effluents of the four plants during Phase III on June 3 and 13, 1969. The results of these tests are presented in Tables 43 and 44. The chlorine dosage ranged between 10 and 17 mg/l to maintain a 0.5 mg/l total chlorine residual in the effluent after 15 minutes detention time.

During October and November, 1969, arrangements were made with the City of Green Bay Health Department Laboratory to jointly conduct coliform count and chlorine residual studies on the pilot plant effluents. Grab samples of pilot plant final effluents were obtained and split into two equal portions (A and B). Aliquot A, analyzed by the Health Department, was divided into five equal volumes; each volume was dosed with zero, 5, 10, 15, and 20 mg/l of chlorine respectively. After 15 minutes contact time, any remaining chlorine in each of the samples was inactivated by adding a small amount of a 10% solution of sodium thiosulfate. Samples from the dosed final effluents were then properly diluted into sterile, buffered, distilled water blanks. Total coliform counts were made by the Membrane Filter Technique, using DIFCO Endo Broth as media. The incubation period was between 18 and 20 hours.

Aliquot B was analyzed for total and volatile suspended solids by the GBMSD laboratory. It was then divided into five equal volumes; each volume was dosedwith zero, 5, 10, 15 and 20 mg/l of chlorine respectively. After 15 minutes contact time, the total residual chlorine was measured by the amperometric titration method.

The results of the chlorine - coliform studies are presented in Table 45. Based upon the studies in June and the studies presented in this Table, the values of 10 and 15 mg/l were chosen respectively as the average and maximum chlorine dosage rates required to maintain the total coliform count at a value less than 5000 per 100 mls of sample.

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FINAL EFFLUENT CHLORINATION

Date	Plant	24-Hour Composite Analyses mg/l		Chlorine Added To Grab Sample of Final Effluent	Total Chlorine Residual After 15 Minutes	Chlorine Addition To Maintain 0.5 mg/l Residual After 15 Minutes
		BOD	TSS	mg/l	mg/l	mg/l
6/3	CS-Variable	39	52	2.43	0	14
				12.13	0.4	
				14.55	0.5	
				16.98	0.7	
				19.40	1.3	
				24.25	1.1	
6/3	CS-Control	48	70	12.13	0.5	12
				13.34	0.9	
				14.55	1.2	
				16.98	1.8	
6/3	K-Variable	30	16	12.13	0.3	14
				14.55	0.6	
				16.98	0.9	
				19.40	1.2	
				21.83	1.4	
				24.25	1.7	
6/3	K-Control	24	26	12.13	0.2	17
				14.55	0.4	
				16.98	0.4	
				19.40	0.7	
				21.83	0.9	
				24.25	1.6	

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FINAL EFFLUENT CHLORINATION

Date 1969	Plant	24-Hour Composite Analyses mg/l BOD	24-Hour Composite Analyses mg/l TSS	Chlorine Added To Grab Sample of Final Effluent mg/l	Total Chlorine Residual After 15 Minutes mg/l	Chlorine Addition To Maintain 0.5 mg/l Residual After 15 Minutes mg/l
6/13	CS-Variable	48	20	9.57	0.2	12
				11.96	0.4	
				14.36	0.8	
				16.75	1.2	
6/13	CS-Control	50	54	9.57	0.3	11
				11.96	0.8	
				14.36	1.5	
6/13	K-Variable	74	38	9.57	0.4	11
				11.96	0.7	
				14.36	1.1	
				16.75	1.9	
6/13	K-Control	70	32	9.57	0.4	10
				11.96	0.9	
				14.36	1.7	

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TOTAL COLIFORM IN FINAL EFFLUENT

Date - 1969	Pilot Plant	TSS, mg/l	VSS, mg/l	Not Chlorinated	5 mg/l	TRC, mg/l	10 mg/l	TRC, mg/l	15 mg/l	TRC, mg/l	20 mg/l	TRC, mg/l
10-2	B	19	15	225,000*	190,000*	0	----	0	----	0.6	----	0.9
10-9	C	44	30	150,000	7,000	0	2700*	1.0	1300*	2.5	500*	4.1
10-23	D	36	--	590,000	7,900	1.8	5820	3.7	100	9.1	100	13.8
11-6	C	39	36	1,490,000	1,000	1.8	600	5.5	90	8.8	40	12.0
11-13	D	68	24	220,000	150,000	.1	8500	.8	1420	1.4	1290	2.2

* Total Coliform per 100 mls of sample

TRC - Total Residual Chlorine

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TOTAL CARBON CORRELATIONS

The procedures for BOD, COD, TSS and total carbon (TC) analyses are presented in the section entitled "Laboratory Staff, Equipment, Procedures and Data Reduction." The following information also pertains to the measurement of total carbon (TC).

1. A 25 microliter, No. 702-N Hamilton syringe was used for the manual injections.
2. The carbonaceous analyzer was fitted with a manual-injection glass tee adapter and rubber septum.
3. Standardization Procedure:
    - A. Each standards injection equaled 19 microliters.
    - B. 500 ppm total carbon standard equaled the midscale value of the recorder.
4. Sample temperature: Approximately 68°F.
5. Sample size:

    0 - 800 mg/l TC: 19 microliters

    800 - 1800 mg/l TC: 9.5 microliters

    > 1800 mg/l TC: sample diluted with CO_2 - free water; 19 microliter sample used
6. Between sample injections, the syringe was rinsed in distilled water several times.

The laboratory technician ran two TC tests on a given sample: if the two values were within 10 mg/l of each other, the values were accepted as reliable; if the values disagreed by more than 10 mg/l, a third test was run. The third value normally agreed within 10 mg/l of one of the first two analyses. These two values were then averaged and the average value reported on the lab data sheet.

The purpose of the total carbon correlation studies was to determine if the BOD of a given sample could be accurately predicted with a known degree of confidence and deviation.

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The following samples were utilized in the correlation studies:

1. Pilot Plant Primary Influent (BOD, TC, TSS)
2. Pilot Plant Primary Effluent (BOD, COD, TC, TSS)
3. Metro Influent (BOD, TC, TSS)
4. Mills 1, 2, 3, and 4 storage contents (BOD, TC, TSS)

The values in parentheses are those tests used in the correlation studies for that particular sample.

The mathematical model used in these correlation studies was as follows:

$\hat{Y} = B_O + B_1 X + e$, where

X = dependent variable

B_O, B_1 = constants

e = estimate of error

With the assistance of Dr. Watts(20), the laboratory data for BOD, COD, TC and TSS were utilized in a computer program to develop the following models:

1. BOD = f(TC)
2. COD = f(TC)
3. BOD = f(COD)
4. BOD = f(TSS)
5. COD = f(TSS)
6. TC = f(TSS)

The average, maximum, minimum and standard deviation values for the laboratory data utilized in the correlation studies and the BOD/TC ratios developed from the laboratory data are presented in Table 46. The average BOD/TC ratio varied from 0.81 (1969 - Mill 4) to 1.24 (1968 - Mill 3).

A summary of the important terms developed in the statistical correlation studies is presented in Tables 47 and 48. A definition of the terms in the Tables is as follows:

B_O & B_1	Regression coefficients
B_{OR} & B_{1R}	Half-magnitude of the 95% confidence interval of respective regression coefficient
Coefficient of Determination	(Multiple correlation coefficient)^2
Standard Error Estimate	Estimate of "e" in model
X	Average value of independent variable

BOD-TOTAL CARBON RATIOS

Sample	No. of Tests	Test	Laboratory Analyses Ave.	Max.	Min.	S.D.	S.D./Avg. %	BOD/TC Ratio Avg.	Max.	Min.	S.D.
1968		BOD	541	765	260	104	19.2				
PP-PI	70	TC	509	771	309	99	19.4	1.07	1.54	0.68	0.16
		TSS	229	396	98	58					
1969		BOD	494	1230	176	94	19.0				
PP-PI	288	TC	499	805	245	66	13.2	0.99	2.52	0.63	0.17
		TSS	221	492	88	65					
1968		BOD	525	720	295	87	16.6	1.04	1.51	0.57	
PP-PE	174	COD	1379	2316	760	225	16.3	(2.77)	(4.12)	(1.33)	(a)
		TC	504	683	390	77	15.3				
		TSS	133	240	360	41					
1969		BOD	457	669	113	85	18.6	0.94	1.94	0.49	
PP-PE	286	COD	1118	1827	509	30	2.7	(2.30)	(3.85)	(1.35)	(a)
		TC	484	870	272	64	13.2				
		TSS	152	404	560	46					
1968		BOD	302	470	121	81	26.8				
METRO	72	TC	248	331	134	44	17.7	1.21	2.09	0.63	0.23
		TSS	243	428	84	75					
1969		BOD	247	510	470	84	34.0				
METRO	289	TC	237	440	129	59	24.9	1.03	2.49	0.33	(a)
		TSS	219	500	680	62					
1968		BOD	1560	2640	1085	412	26.4				
MILL 1	14	TC	1315	1732	825	242	18.4	1.19	2.09	0.97	0.29
		TSS	157	264	40	82					
1969		BOD	1432	2085	525	422	30.0				
MILL 1	34	TC	1409	1978	705	321	31.8	1.01	1.51	0.38	0.21
		TSS	217	1140	23	199					
1968		BOD	904	1410	503	271	16.6				
MILL 2	16	TC	1000	1604	531	318	12.7	0.92	1.20	0.46	0.18
		TSS	171	428	54	113					
1969		BOD	740	1206	510	146	69.0				
MILL 2	27	TC	907	1367	543	203	45.0	0.83	1.11	0.60	0.15
		TSS	138	578	36	112					
1968		BOD	578	748	390	96	29.5				
MILL 3	23	TC	463	608	331	59	22.8	1.24	1.53	0.88	0.15
		TSS	214	412	68	80					
1969		BOD	570	788	420	77	19.7				
MILL 3	54	TC	506	891	381	83	22.4	1.13	1.49	0.78	0.16
		TSS	273	1230	56	185					
1968		BOD	1521	6000	675	1050	13.5				
MILL 4	22	TC	1686	3670	771	758	16.4	0.90	1.63	0.36	0.25
		TSS	292	706	80	138					
1969		BOD	1150	1875	765	241	21.0				
MILL 4	28	TC	1437	2093	998	295	20.5	0.81	1.05	0.60	0.14
		TSS	406	950	84	201					

( ) COD/TC Ratio
(a) Data not available

NOTE: BOD, COD, TC and TSS are in mg/l.

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BOD AND TOTAL CARBON MODELS

Parameter Dep.	Ind.	B_O	B_{OR}	B_1	B_{1R}	Coef. of Det.	Std. Err. Est.	X Average	$\hat{Y}$	± % About Average C_1	± % About Average C_2
PP-PI - 68											
BOD	TC	148.2	45.1	0.77	0.09	0.54	71.4	509	540	3.1	25.9
BOD	TSS	418.7	49.1	0.53	0.21	0.09	100.1	229	541	4.4	36.4
TC	TSS	473.3	48.6	0.16	0.21	0.01	99.1	229	509	4.7	27.9
PP-PI - 69											
BOD	TC	155.1	37.4	0.68	0.07	0.23	83.1	499	494	2.0	32.2
BOD	TSS	401.5	19.1	0.42	0.08	0.08	90.5	221	494	2.2	35.0
TC	TSS	437.6	13.4	0.28	0.06	0.07	63.7	221	499	1.4	24.4
PP-PE - 68											
BOD	TC	160.6	33.5	0.72	0.07	0.41	66.9	504	525	1.9	24.4
COD	TC	391.3	83.8	1.96	0.16	0.45	167.2	504	1379	1.8	23.2
BOD	TSS	447.8	21.6	0.58	0.16	0.08	83.9	133	525	2.5	30.7
COD	TSS	1258.6	57.5	0.91	0.41	0.03	222.8	133	1379	2.4	31.0
TC	TSS	486.1	19.9	0.14	0.14	0.01	77.3	133	504	4.2	29.6
BOD	COD	103.6	25.2	0.31	0.12	0.63	53.4	1379	526	1.5	19.4
PP-PE - 69											
BOD	TC	57.6	30.1	0.83	0.06	0.38	66.4	484	457	1.8	27.8
COD	TC	14.5	118.7	2.28	0.24	0.24	261.7	484	1117	2.7	44.9
BOD	TSS	374.9	16.8	0.54	0.11	0.08	81.2	152	457	2.0	33.9
COD	TSS	815.2	58.9	1.99	0.37	0.09	285.3	152	1117	3.0	14.1
TC	TSS	416.1	12.5	0.45	0.08	0.10	60.5	152	484	1.4	112.6
BOD	COD	247.6	14.6	0.19	0.01	0.44	63.5	1118	458	1.5	26.4
METRO - 68											
BOD	TC	48.0	35.4	1.41	0.14	0.59	52.2	248	398	3.0	25.6
BOD	TSS	123.2	24.0	0.74	0.09	0.46	59.6	243	302	4.6	38.4
TC	TSS	167.9	14.8	0.33	0.06	0.31	36.7	243	248	3.6	29.0
METRO - 69											
BOD	TC	21.0	15.4	0.96	0.06	0.44	63.1	237	249	2.8	48.6
BOD	TSS	66.9	14.5	0.82	0.06	0.37	67.3	219	247	5.3	52.2
TC	TSS	130.6	10.9	0.48	0.05	0.26	50.6	219	235	2.6	41.3

Table 47

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BOD AND TOTAL CARBON MODELS

Parameter Dep.	Ind.	B_O	B_{OR}	B_1	B_{1R}	Coef. of Det.	Std. Err. Est.	X Average	$\hat{Y}$	± % About Average C_1	± % About Average C_2
MILL 1 - 68											
BOD	TC	435.2	567.2	0.86	0.43	0.25	370.9	1315	1560	13.8	52.2
BOD	TSS	1995.8	212.9	-2.79	1.22	0.31	357.7	157	1559	13.3	50.4
TC	TSS	1652.1	103.3	-2.15	0.59	0.53	173.6	157	1314	7.7	29.0
MILL 1 - 69											
BOD	TC	108.0	234.8	0.94	0.16	0.51	299.8	1409	1433	7.3	42.2
BOD	TSS	1297.9	104.7	0.62	0.36	0.09	410.0	217	1432	10.0	57.8
TC	TSS	1410.5	83.3	-0.01	0.29	0.00	326.1	217	1409	8.1	46.7
MILL 2 - 68											
BOD	TC	325.2	174.2	0.58	0.17	0.46	205.3	1000	904	12.2	48.9
BOD	TSS	970.3	128.6	-0.39	0.63	0.03	276.6	171	904	16.4	65.9
TC	TSS	1123.8	148.0	-0.72	0.73	0.07	318.4	171	1000	17.1	68.6
MILL 2 - 69											
BOD	TC	307.9	100.1	0.48	0.11	0.44	111.7	907	740	5.9	30.9
BOD	TSS	773.2	45.1	-0.25	0.26	0.04	146.3	138	739	7.8	40.5
TC	TSS	901.9	63.9	0.04	0.36	0.00	207.3	138	908	9.0	46.7
MILL 3 - 68											
BOD	TC	104.9	128.2	1.02	0.28	0.40	76.5	463	578	5.7	27.5
BOD	TSS	509.2	58.0	0.32	0.25	0.07	95.0	214	577	7.1	34.1
TC	TSS	445.4	36.9	0.09	0.16	0.01	60.4	214	463	5.6	27.0
MILL 3 - 69											
BOD	TC	342.2	58.3	0.45	0.11	0.23	68.4	506	570	3.3	23.7
BOD	TSS	551.9	18.8	0.07	0.06	0.03	77.1	273	570	3.7	26.8
TC	TSS	493.2	20.3	0.05	0.06	0.01	83.0	273	506	4.5	32.4
MILL 4 - 68											
BOD	TC	-114.0	406.8	0.97	0.22	0.49	768.0	1686	1521	22.4	105.3
BOD	TSS	1474.6	546.7	0.16	1.70	0.00	1075.8	292	1521	31.6	146.8
TC	TSS	1627.4	384.6	0.20	1.23	0.00	776.7	292	1686	20.5	95.6
MILL 4 - 69											
BOD	TC	358.7	172.8	0.55	0.12	0.46	180.7	1437	1150	6.1	32.0
BOD	TSS	1031.6	102.8	0.29	0.23	0.06	237.7	406	1151	8.0	42.1
TC	TSS	1346.2	128.5	0.22	0.29	0.02	297.2	406	1437	7.9	42.1

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$\hat{Y}$ ----------------------- Predicted value of dependent variable based upon average value of X

C_1 ----------------------- Half-magnitude of the 95% confidence interval at the mean for the regression line

C_2 ----------------------- Half-magnitude of the 95% confidence interval at the mean for a future predicted value

In evaluating the models, the following information was obtained:

1. The correlation for the model BOD = f(COD) was better than for the model BOD = f(TC) in the two cases of direct comparison, PP-PE 68 and PP-PE 69.
2. The correlation of BOD, COD and TC with TSS was poor for all samples except Metro and Mill 1.
3. The 95% confidence intervals about the mean for the regression lines vary between ± 1.4% and ± 31.6%.
4. The 95% confidence intervals about the mean for the future predicted values vary between ± 14.1% and ± 105.3%.
5. The Mill samples are much more variable than the Metro samples or the combination of Metro and Mill samples.

Due to the large amount of data utilized in the studies, a very narrow 95% confidence interval results for the regression lines. However, due to the high variability of the individual data, wide 95% confidence intervals resulted for the future predicted values.

In conclusion, these studies showed that using a carbonaceous analyzer to predict BOD values for these samples would be of questionable value. However, should the parameter of total carbon replace BOD in the environmental control field at some future date, there would be less variation in the data from similar research projects. For the studies reported herein, the ratio of standard deviation to average value for the TC tests was normally less than for the BOD tests.

(A similar study was conducted by R. B. Schaffer, et al, and is presented in an article entitled, "Application of a Carbon Analyzer in Waste Treatment", Journal Water Pollution Control Federation, November, 1965.)

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The project was governed by a Steering Committee composed of the following members:

Green Bay Metropolitan Sewerage District
---Mr. David W. Martin

Pulp and Paper Mills
  American Can Company-------------Mr. Bruce B. Robertson
  Charmin Paper Products Company---Mr. Clyde R. Faulkender
  Fort Howard Paper Company-------- Mr. David F. Pagel
  Green Bay Packaging Inc.-----------Mr. William R. Nelson

Donohue & Associates, Inc., Engineering Consultants
---Mr. William O. White

University of Wisconsin, Special Consultant
---Dr. L. B. Polkowski

Wisconsin Department of Natural Resources
---Mr. Carl G. Blabaum

Those persons responsible for the daily administration and operation of the research project were Mr. Karl G. Voelkel - Research Director, Mr. Robert W. Deering - Laboratory Director, Mr. Larry R. Wilms - Project Engineer, Mrs. Betty Liebman - Project Accountant, Mr. Willard DeBauche, Jr. - Special Studies Technician, Miss Lynda Bentley - Microbiologist, and Miss Kathleen Nowicki - Secretary. In addition, Mr. Dean Burns - Laboratory Technician and Mr. James Zimmer - Microbiologist were associated with the initial development of the research program. Mr. Voelkel and Mr. Wilms were associated with Donohue & Associates, Inc. The remaining persons were members of the GBMSD staff.

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20. Personal Correspondence, Watts, D. G., Professor, Dept. of Statistics, University of Wisconsin, Madison, Wisconsin.

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APPENDIX A

PILOT PLANT FACILITIES

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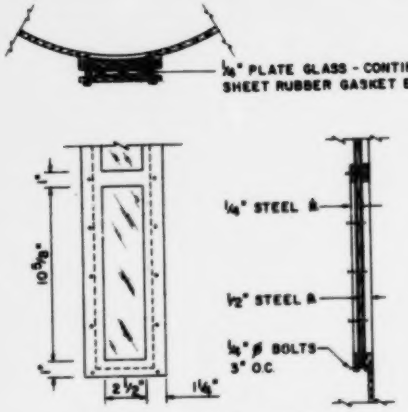
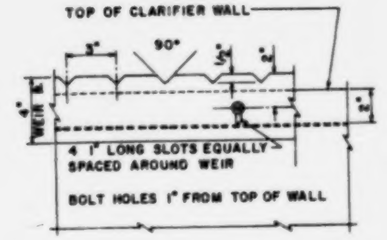
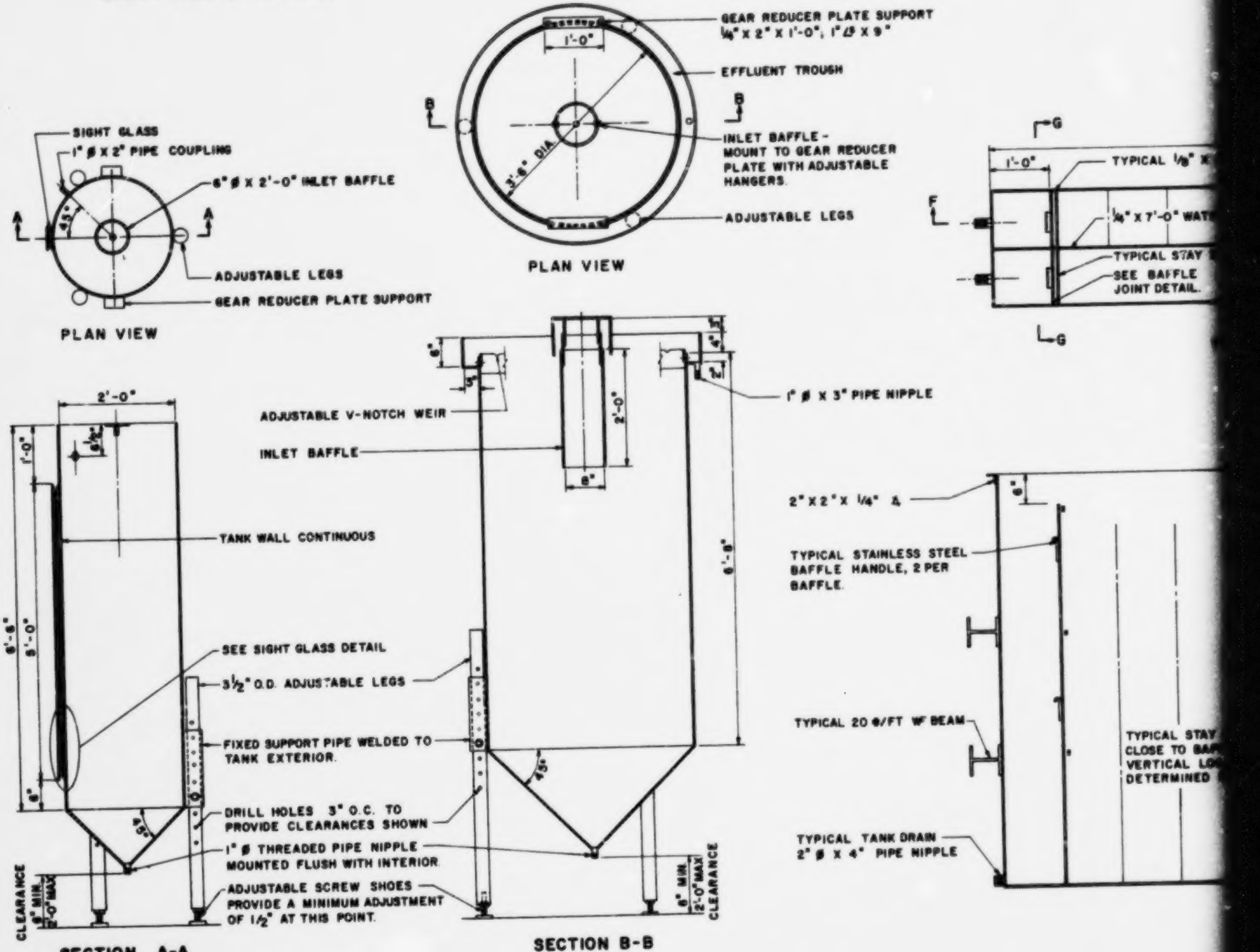

1/4" PLATE GLASS - CONTINUOUS
SHEET RUBBER GASKET EACH SIDE.
1/4" STEEL ℞
1/2" STEEL ℞
1/4" ø BOLTS-
3" O.C.
10 5/8"
1"
1"
2 1/2"
1 1/4"

SIGHT GLASS DETAIL


TOP OF CLARIFIER WALL
3"
90°
1/2"
2"
4"
WEIR ℞
2"
4 1" LONG SLOTS EQUALLY
SPACED AROUND WEIR
BOLT HOLES 1" FROM TOP OF WALL

PRIMARY CLARIFIER WEIR DETAIL


SIGHT GLASS
1" ø X 2" PIPE COUPLING
6" ø X 2'-0" INLET BAFFLE
45°
A
A
ADJUSTABLE LEGS
GEAR REDUCER PLATE SUPPORT
GEAR REDUCER PLATE SUPPORT
1/4" X 2" X 1'-0"; 1" ∠ X 9"
1'-0"
EFFLUENT TROUGH
B
B
3'-6" DIA.
INLET BAFFLE -
MOUNT TO GEAR REDUCER
PLATE WITH ADJUSTABLE
HANGERS.
ADJUSTABLE LEGS
2'-0"
1'-0"
1 1/2"
TANK WALL CONTINUOUS
6'-6"
5'-0"
6"
45°
SEE SIGHT GLASS DETAIL
3 1/2" O.D. ADJUSTABLE LEGS
FIXED SUPPORT PIPE WELDED TO
TANK EXTERIOR.
DRILL HOLES 3" O.C. TO
PROVIDE CLEARANCES SHOWN
1" ø THREADED PIPE NIPPLE
MOUNTED FLUSH WITH INTERIOR.
ADJUSTABLE SCREW SHOES
PROVIDE A MINIMUM ADJUSTMENT
OF 1/2" AT THIS POINT.
CLEARANCE
6" MIN.
2'-0" MAX
6"
3"
ADJUSTABLE V-NOTCH WEIR
INLET BAFFLE
2'-0"
6"
4"
1"
1" ø X 3" PIPE NIPPLE
6'-8"
45°
6" MIN.
2'-0" MAX
CLEARANCE
G
1'-0"
TYPICAL 1/8" X
F
1/4" X 7'-0" WAT
TYPICAL STAY
SEE BAFFLE
JOINT DETAIL.
G
2" X 2" X 1/4" ∠
6"
TYPICAL STAINLESS STEEL
BAFFLE HANDLE, 2 PER
BAFFLE.
TYPICAL 20 #/FT WF BEAM
TYPICAL STAY
CLOSE TO BA
VERTICAL LO
DETERMINED
TYPICAL TANK DRAIN
2" ø X 4" PIPE NIPPLE

PLAN VIEW

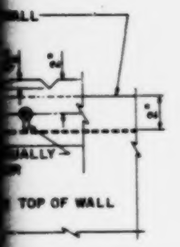
SECTION A-A

FINAL CLARIFIER

PLAN VIEW

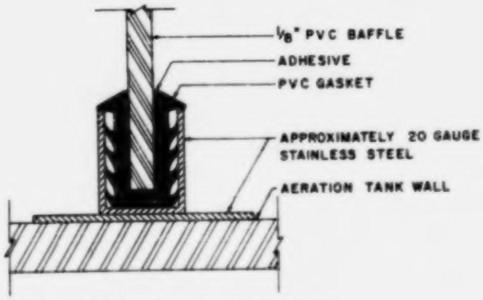
SECTION B-B

PRIMARY CLARIFIER



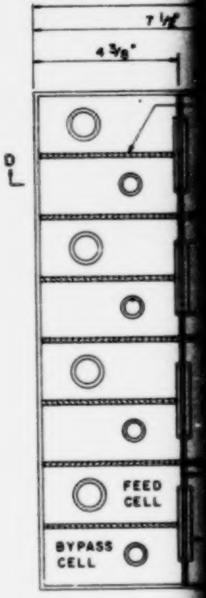
ALL
2"
ALLY
TOP OF WALL

R WEIR DETAIL



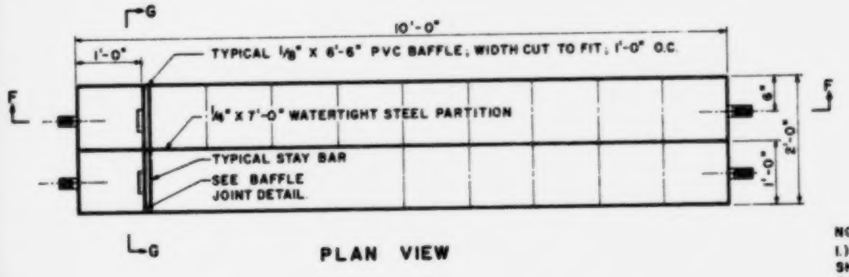
1/8" PVC BAFFLE
ADHESIVE
PVC GASKET
APPROXIMATELY 20 GAUGE STAINLESS STEEL
AERATION TANK WALL

TYPICAL BAFFLE JOINT DETAIL



7 1/2"
4 3/8"
D
FEED CELL
BYPASS CELL

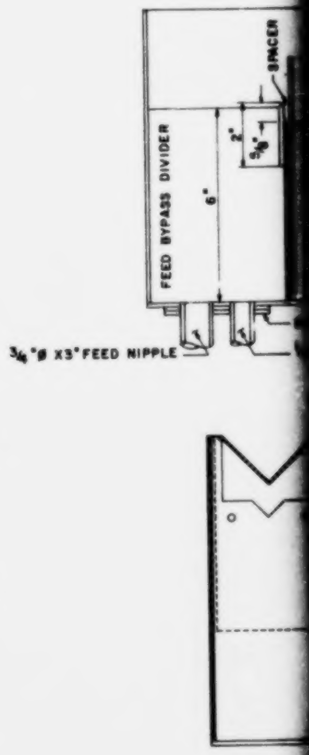
GENERAL NOTE:
INITIAL PROTECTIVE COATINGS ON PRIMARY & FINAL CLARIFIERS AND AERATION TANKS (INSIDE & OUTSIDE) OF 2-PART COLD-SET EPOXY RESIN.



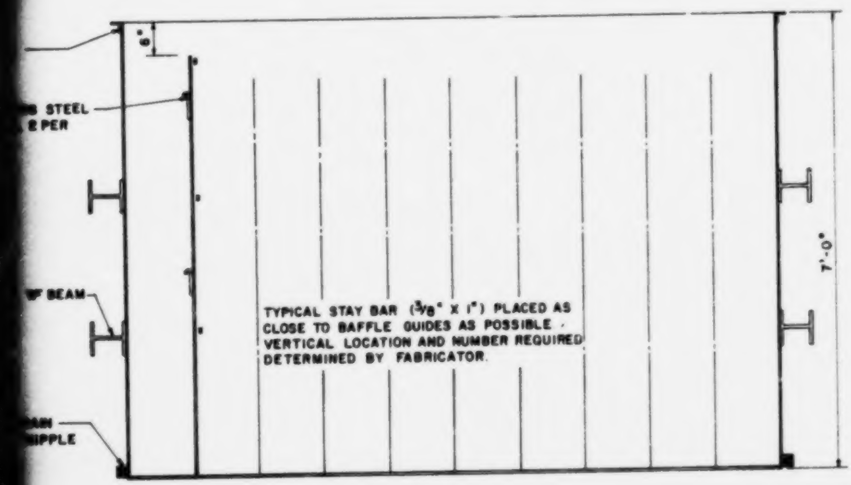
G
10'-0"
1'-0"
TYPICAL 1/8" X 6'-6" PVC BAFFLE; WIDTH CUT TO FIT; 1'-0" O.C.
F
1/4" X 7'-0" WATERTIGHT STEEL PARTITION
TYPICAL STAY BAR
SEE BAFFLE JOINT DETAIL.
6"
2'-0"
1'-0"
F
G

PLAN VIEW

NOTE:
1.) TOP ∠s & I BEAMS NOT SHOWN ON PLAN VIEW.
2.) BAFFLE JOINTS TO BE AS WATERTIGHT AS POSSIBLE SEE DETAIL.



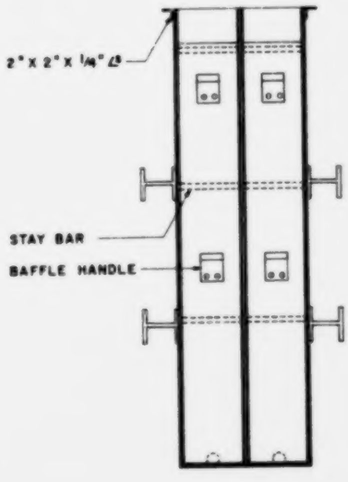
SPACER
2"
5/8"
6"
FEED BYPASS DIVIDER
3/4"ø X3" FEED NIPPLE



6"
S STEEL
, 2 PER
W BEAM
AIN
IPPLE
7'-0"

TYPICAL STAY BAR (3/8" X 1") PLACED AS CLOSE TO BAFFLE GUIDES AS POSSIBLE. VERTICAL LOCATION AND NUMBER REQUIRED DETERMINED BY FABRICATOR.

SECTION F-F



2" X 2" X 1/4" ∠s
STAY BAR
BAFFLE HANDLE

SECTION G-G

SEC

AERATION TANK

FE

BAFFLE

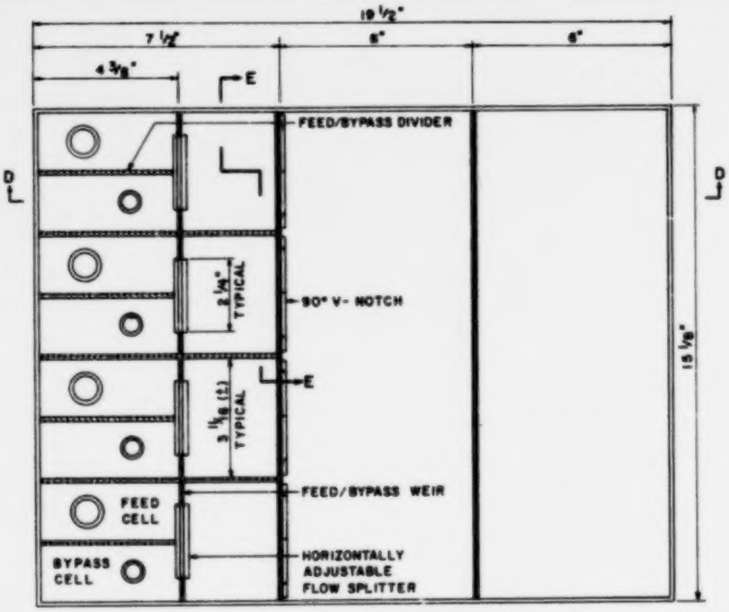
E

ET

ATELY 20 GAUGE
D STEEL

N TANK WALL

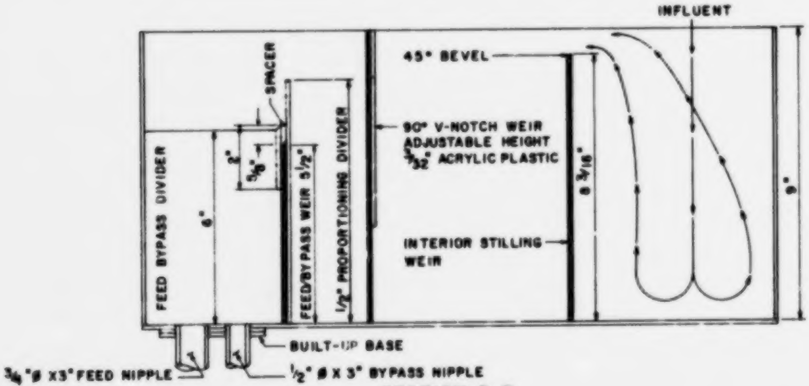
AL NOTE:
L PROTECTIVE COATINGS ON
RY & FINAL CLARIFIERS AND
ION TANKS (INSIDE & OUTSIDE)
-PART COLD-SET EPOXY RESIN.



19 1/2"
7 1/2"
6"
6"
4 3/8"
E
D
D
FEED/BYPASS DIVIDER
2 1/2" TYPICAL
90° V- NOTCH
3 11/16 (±) TYPICAL
E
FEED/BYPASS WEIR
FEED CELL
BYPASS CELL
HORIZONTALLY ADJUSTABLE FLOW SPLITTER
15 1/8"

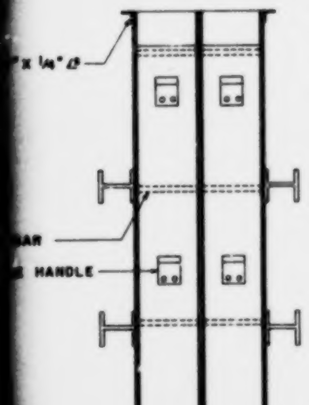
PLAN VIEW

∠ & I BEAMS NOT
ON PLAN VIEW.
PLE JOINTS TO BE
ERTIGHT AS POSSIBLE
TAIL.

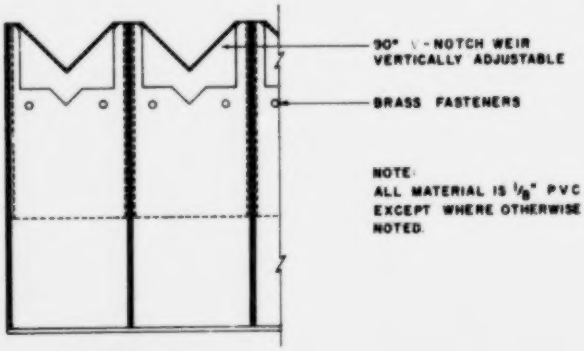


INFLUENT
SPACER
45° BEVEL
90° V-NOTCH WEIR ADJUSTABLE HEIGHT 3/32" ACRYLIC PLASTIC
FEED BYPASS DIVIDER
6"
3/8"
2"
FEED/BYPASS WEIR 5 1/2"
1/2" PROPORTIONING DIVIDER
8 3/16"
9"
INTERIOR STILLING WEIR
BUILT-UP BASE
3/4" ø X 3" FEED NIPPLE
1/2" ø X 3" BYPASS NIPPLE

SECTION D-D



" x 1/4" ∠
AR
HANDLE



90° V-NOTCH WEIR VERTICALLY ADJUSTABLE
BRASS FASTENERS

NOTE:
ALL MATERIAL IS 1/8" PVC
EXCEPT WHERE OTHERWISE
NOTED.

SECTION G-G

SECTION E-E

FEED-BY PASS SPLITTER BOX

DONOHUE & ASSOCIATES, INC.
CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN

GREEN BAY METROPOLITAN SEWAGE DISTRICT
INDUSTRIAL-MUNICIPAL RESEARCH PROJECT
PILOT PLANT - TANK FABRICATION - AS BUILT

SHEET NO.
1 OF 1

FILE NO.
K-25274

294

APPENDIX B

LABORATORY PROCEDURES
AND
DATA REDUCTION

MICRO KJELDAHL NITROGEN ANALYSES

Equipment Required

Complete Micro Kjeldahl Nitrogen Apparatus (Keeney Still), including side arm flasks and receiving flasks; 0.2 g. Hach Spoon.

Procedure

A. Ammonia - N

1. Place a 10 ml. sample (or aliquot size sample diluted to 10 mls.) in a side arm flask.
2. Add approximately 0.2 g. of magnesium oxide to the flask, swirl to mix, stopper, and place on distillation apparatus.
3. Pipet 5 mls of boric acid indicating solution into a receiving flask and place in position.
4. Close steam bypass and begin distillation.
5. When there is approximately 35 mls. of distillate in the receiving flask open the steam bypass again.
6. Titrate the distillate with 0.005 NH_2SO_4 titrant. The end point is a pink-red color, a change from green.

B. Nitrate - N

1. Using the same sample size as for ammonia - N, add 0.2 g. magnesium oxide and swirl.
2. Add 1 ml. of sulfamic acid solution, (to destroy nitrite) and swirl.
3. Distill off approximately 30 mls to remove ammonia. (This can be titrated and used for ammonia - N as above.)
4. Open steam bypass. Then add 0.2 g of Devarda's Alloy to the sample.
5. Stopper the flask, close the steam bypass and collect 35 mls of distillate in another receiving flask containing 5 mls of boric acid indicating solution.
6. Titrate as in Step A-6.

C. Nitrite - N

1. Place a 10 ml (or aliquot size) sample in a side arm flask.
2. Add 0.2 g magnesium oxide and 0.2 g of Devarda's Alloy and distill as normal. This distillate will yield ammonia + nitrite + nitrate.
3. Titrate as in Step A-6.
4. Place another 10 mls of the same sample into another side arm flask.

5. Add approximately 0.2 g magnesium oxide and 1 ml of sulfamic acid. Swirl to mix. Allow to stand for about one minute to insure nitrite destruction.
6. Add 0.2 g Devarda's Alloy and distill. This distillation yields ammonia + nitrate.
7. Titrate as in Step A-6.
8. Determine nitrite by difference.

Calculations

A curve of nitrogen standards, prepared on rectangular graph paper, should be made by distilling known concentrations of ammonia-N and titrating the distillates. The curve is made by plotting concentration (mg/l as N) versus volume of titrant (0.005 NH_2SO_4) used to titrate the distillates. The slope of the line is then determined and an equation is derived so that the concentration of nitrogen can be calculated by inserting the volume of titrant into the equation.

Reagents

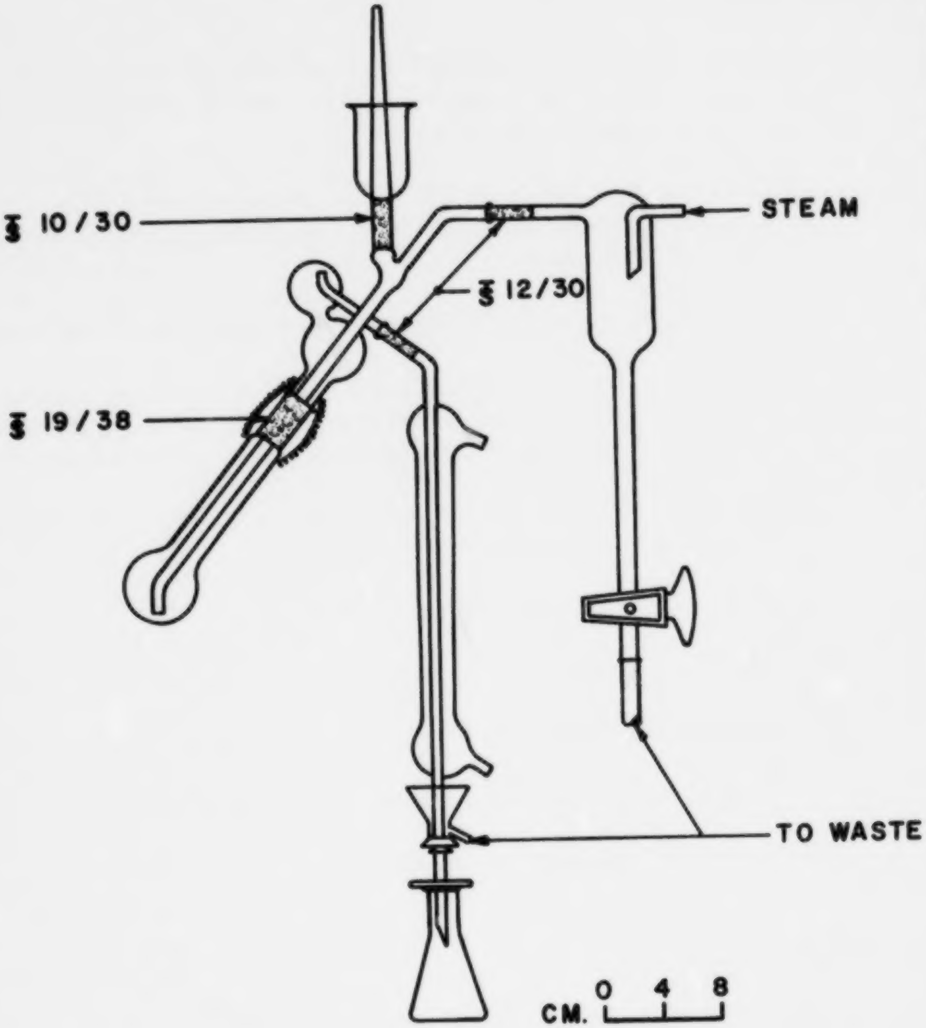
Boric Acid Indicator Solution - Prepared according to Section 2.2 - Reagents, part 2, page 3 of Bremner, J. M. and D. R. Keeney, 1966, Soil Sci. Soc. Amer. Proc. Report.

Sulfuric Acid, 0.005 N - Prepared from a 1 N stock solution.

Nitrogen Standard Solutions - Prepared by dissolving 3.819 g NH_4Cl in one liter of ammonia-free H_2O. From this stock solution various dilutions are made and used to plot the nitrogen standard curve. (Stock solution: 1 ml = 1.0 mg N.)

Magnesium Oxide
Devarda's Alloy
Purchased from Chemical Companies.

MICRO KJELDAHL APPARATUS



$\overline{\$}$ 10/30
STEAM
$\overline{\$}$ 12/30
$\overline{\$}$ 19/38
TO WASTE
CM. 0 4 8

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ORTHO AND TOTAL PHOSPHORUS ANALYSES

The lab procedure used for determining phosphates is an adaptation of that presented in an Association of American Soap and Glycerine Producers report "Determination of Orthophosphate, Hydrolyzable Phosphate, and Total Phosphate in Surface Waters" in the American Water Works Association Journal, December, 1958.

A. Apparatus

All glassware must be carefully washed with phosphate-free soap (Liqui-Nox), rinsed well with tap water, and then rinsed at least three (3) times with distilled water.

1. Spectrophotometer or electrophotometer, red filter, wavelength approximately 620-630 mu, optical cells with light path of 20-25 mm.

2. Automatic pipet, calibrated, 50-ml capacity, with reservoir.

3. Pipets, calibrated, 25 ml, 10 mg, 5 ml, 1 ml. Safety aspirator, (the safety aspirator used in these tests was the "Propipet" manufactured by Will Corp., Rochester, N.Y.).

4. Graduated extraction cylinder, 100 ml, with well-fitting ground-glass stoppers.

5. Volumetric flasks, 50 ml.

6. Beakers, 250 ml.

7. Graduated cylinders, 100 ml.

8. Glass beads or Hengar granules, 1-2 mm diameter.

9. Hotplate, rheostat-controlled.

B. Reagents

1. Potassium persulfate, ACS reagent grade.

2. Potassium phosphate, monobasic, anhydrous, ACS (American Chemical Society) reagent grade. Dry at 110° C for one hour. Cool in a desiccator prior to weighing.

3. Sulfuric acid, 8 N.; Dilute 222 ml of concentrated H_2SO_4, (ACS reagent grade, sp.gr.-1.84) to one liter with distilled water.

4. Ammonium molybdate solution, neutral, 10 per cent. Dissolve 100 g of $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$, ACS reagent grade and dilute to one liter with distilled water. Store in brown, stoppered bottle.

5. Acidic molybdate reagent. Equal volumes of 8 N sulfuric acid and ammonium molybdate solution (see reagent number 4) are mixed. Store in stoppered bottles.

6. Benzene-isobutanol solvent. Equal volumes of benzene and isobutanol, both ACS reagent grade, are mixed.

7. Stock stannous chloride solution. Ten grams of $SnCl_2 \cdot 2H_2O$ are dissolved in 25 ml of concentrated HCl, both ACS reagent grade. Solution should be freshly prepared every (2) weeks and stored in a dark, stoppered bottle.

8. Sulfuric acid, 1 N. Dilute 27.7 ml of concentrated H_2SO_4 (ACS reagent grade, sp.gr-1.84) to one liter with distilled water.

9. Diluted stannous chloride solution. Add 0.5 ml of stannous chloride solution (reagent number 7) to 100 ml sulfuric acid (reagent number 8). Prepare daily.

10. Methyl alcohol, ACS reagent grade.

11. Alcoholic sulfuric acid: Mix 20 ml of concentrated H_2SO_4 (ACS reagent grade, sp.gr.-1.84) with 980 ml of methyl alcohol, with adequate stirring.

C. Procedure

1. Ortho Phosphate

Preparation of calibration curve. Dissolve 0.1917 g KH_2PO_4 in one liter of distilled water. This standard solution (Std. 1) contains 0.1 mg (100 ug) P_2O_5 per milliliter. Dilute 50 ml of this solution to one liter to obtain standard solution (Std. 2) which contains 0.005 mg (5 ug) P_2O_5 per milliliter. Pipet 5, 10, 20, and 30 ml aliquots of standard solution (Std. 2) into separate 100-ml graduated extraction cylinders and dilute to 40 ml with distilled water. Add exactly 50 ml of the benzene-isobutanol mixture from an automatic pipet. Measure 15 ml (± 0.1 ml) of the acidic molybdate reagent in a 25-ml graduate, pour it into the 100-ml graduated extraction cylinder containing the sample and the organic solvent, close immediately, and shake vigorously without delay for exactly 15 seconds. (The time must be watched carefully when analyzing mixtures of orthophosphates and condensed phosphates. Considerable error could be caused by hydrolysis of condensed phosphates.) Remove the stopper of the graduated extraction cylinder and, as soon as the layers have separated, withdraw a 25 ml aliquot of the supernatant organic solvent with a calibrated 25-ml pipet, using a safety aspirator. Transfer the aliquot into a 50-ml volumetric flask, add about 15 ml alcoholic sulfuric acid, and swirl. Add 1 ml diluted stannous chloride solution, swirl, and make to the mark with alcoholic sulfuric acid. Mix well and allow to stand 10 minutes before reading percentage transmission at 620 mu. Measure within 30 minutes against the blank. Set up the calibration curve by plotting micrograms of P_2O_5 against the percentage transmission.

2. Total Phosphate

Analysis for total P_2O_5 plus orthophosphate P_2O_5. Add 0.5 grams of potassium persulfate and 8 ml of 8 N sulfuric acid to an appropriate aliquot and dilute to 48 ml with distilled water in a 150-ml beaker. Add two Hengar granules, or several glass beads, to avoid bumping, cover with a close-fitting, non-ribbed watch glass, and boil gently for 40 minutes. Do not evaporate to dryness. Add 8 ml of 8 N sulfuric acid plus potassium persulfate and dilute to 48 ml with distilled water in another 150-ml beaker and carry it through the whole procedure as a blank. After cooling, transfer the acid solution into a 100-ml graduated extraction cylinder and rinse the beaker and granules, or beads, with a few milliliters of water. Make up to 48 ml with distilled water. Add exactly 50 ml benzene-isobutyl alcohol mixture and 8 ml neutral (10 per cent) ammonium molybdate solution. Stopper the cylinder and shake vigorously for at least 15 seconds. In this procedure, extension of the shaking period does not affect the result since all reversion of the hydrolyzable P_2O_5 has been completed in the preceding hydrolysis step. The analysis is completed as described in Sec. C-1 -- Ortho Phosphate Analyses.

D. Calculations

1. Orthophosphate P_2O_5 (mg/l) = $\frac{P_2O_5 \text{ from calibration curve (ug)}}{\text{sample (ml)}}$

2. Total P_2O_5 (mg/l) = $\frac{P_2O_5 \text{ from calibration curve (ug)}}{\text{sample (ml)}}$

3. Amount of PO_4 (mg/l) = P_2O_5 (mg/l)x 1.34

4. Amount of P (mg/l) = P_2O_5 (mg/l) x .437

Note: All results are normally reported as P

COLOR ANALYSES

Equipment Required

Spectronic 20
Bauch & Lomb Inc.
Cat. No. 33-29-61-62

1/2" I.D. Test Tubes

1/2" I.D. Test Tube Receiver for Spec. 20
Wavelength Range: 340-700 millimicrons

Method of Analysis

1. Filter all samples through Whatman #5 filter paper.

2. Just prior to analysis, the pH of the sample should be adjusted to 7.6 by adding H_2SO_4 or NAOH as required.

3. Place the sample to be analyzed into a 1/2" I.D. test tube. The sample should be at room temperature. If not, moisture will develop on the outside of the test tube and interfere with the transmittance reading on the Spec. 20.

4. Set the Spec. 20 at 375 mu wavelength and allow 1/2 hour warm up time. Span the "% transmittance scale" as follows:

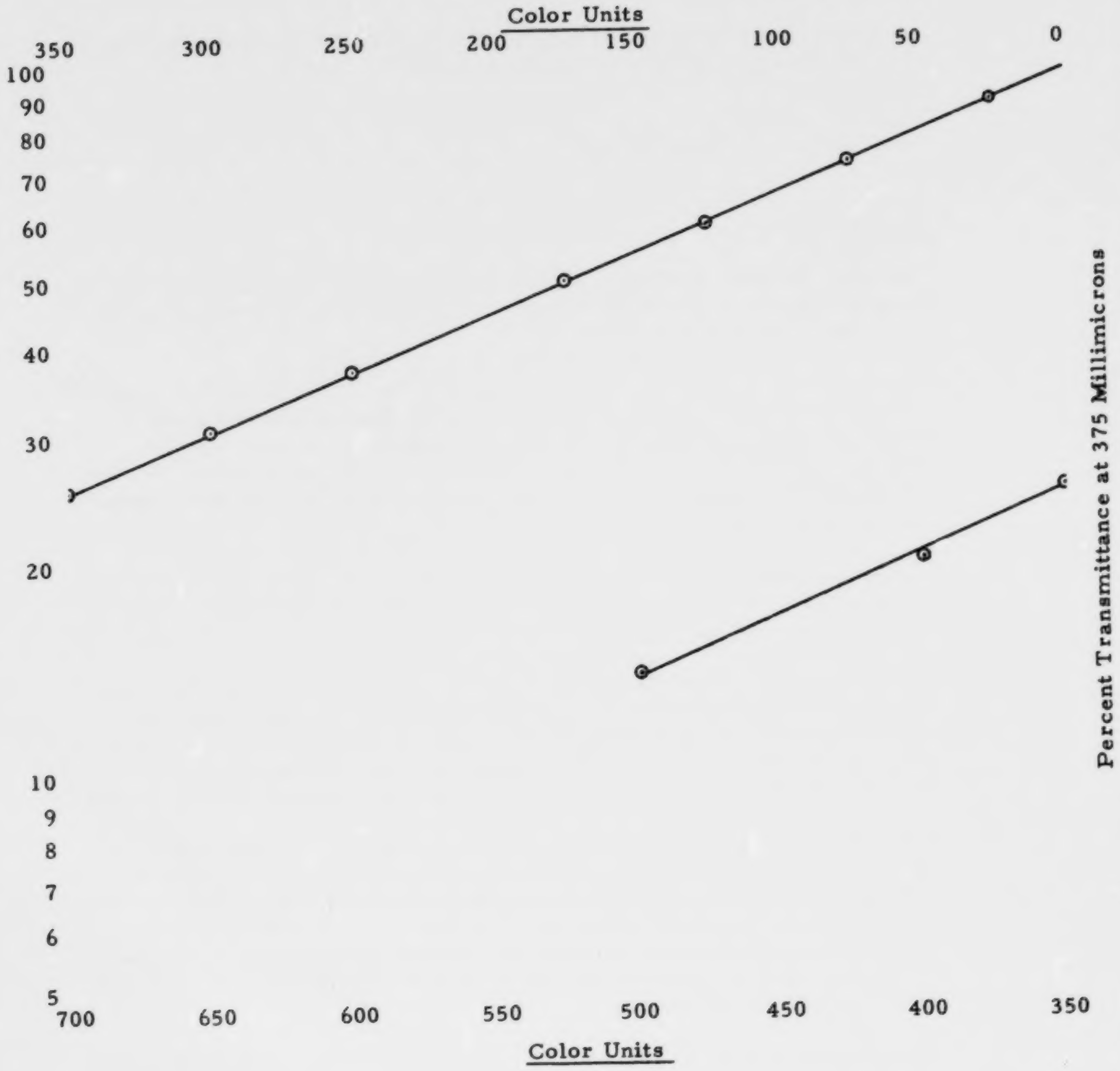
   A) Adjusting the left dial, set needle at 0% transmittance.
   B) Using distilled H_2O as a blank (0 color units), place test tube into receiver. Adjust the right dial until the needle reads 100% transmittance. Remove test tube and recheck the 0% transmittance setting. If necessary, readjust, and then recheck 100% transmittance until both limits are set.

5. Insert test tubes with samples and read % transmittance.

6. To determine the sample's color unit value, read the transmittance value on the "Curve of Platinum-Cobalt Standards".

CURVE OF PLATINUM COBALT STANDARDS

Percent Transmittance vs Color Units



OXYGEN UPTAKE PROCEDURE

Equipment Required

Dissolved oxygen meter with automatic temperature compensation and direct readout of dissolved oxygen in mg/l.
BOD bottles
Magnetic stirrer
Graph paper - rectangular grid

Introduction

Two basic procedures were utilized for oxygen uptake analyses; studies were conducted on subreactors and also by utilizing the contents of the pilot plant aeration tanks directly.

The subreactor study is outlined in the section of this procedure entitled "Contact Stabilization-Control Process (B)"; this is the report of analyses conducted May 21, 1969. This report illustrates how two separate subreactors were used to obtain the total oxygen required for the reaeration section and the contact section and the total BOD removed in the contact section.

Oxygen uptakes conducted in-plant, September 15, 1969, are illustrated in the section of this procedure entitled "Contact Stabilization Process-Plant D-Oxygen Uptake Study."

The assumptions in a subreactor study are that, by utilizing the return activated sludge and fresh primary effluent for a specific plant, the conditions of aeration are fixed with regard to detention time, oxygen level and solids concentration. Therefore, specific values can be obtained for the quantity of oxygen required per pound of BOD removed.

The assumptions for in-plant oxygen uptake studies are that in a continuous flow system the conditions under which the tests are conducted are more realistic. The oxygen uptake analyses for the selected points in the aeration tank are conducted in sequence as rapidly as possible. Assuming a constant flow through the aeration tanks during the period of testing, oxygen uptake rates, as a function of location (detention time) in the tanks, can be obtained.

The procedure used to specifically measure the oxygen uptake in each case is presented; the methods used to calculate the pounds of oxygen required per pound of BOD removed are detailed for each of the four flow schematics. These procedures are applicable to either a subreactor study or an in-plant study.

The number of O_2 uptake tests to be run on a subreactor is a function of the theoretical detention time of the contact section of the process being studied and the shape of the O_2 uptake rate versus time curve. The tests should be continued beyond the theoretical detention time and an adequate number of analyses should be made to accurately define the shape of the curve.

In the case of in-plant studies, the tests should be conducted as quickly as possible to minimize the ratio of total time of studies for the contact or reaeration section to the theoretical detention time in the respective section.

Procedure

1. Obtain approximately 500 ml of mixed liquor either from the subreactor or the desired section of the aeration tank.

2. Aerate the 500 ml sample with pure O_2 to obtain about 10-15 mg/l dissolved oxygen in the sample.

3. Immediately pour about 300 mls of the aerated sample into a BOD bottle; insert a magnetic stirrer bar and place the dissolved oxygen probe in the top of the bottle. Be sure the bottle is sufficiently full so that oxygen bubbles are not entrained beneath the probe.

4. Place the bottle on a Magnastir. Maintain a constant Magnastir speed during the entire study.

5. When the dissolved oxygen meter reading has steadied, read the initial D.O. (Time: 0).

6. Continue to read the dissolved oxygen content a minimum of every minute for approximately 10 minutes or until the D.O. content becomes less than 0.5 mg/l.

7. Plot the measured dissolved oxygen content (mg/l), (on the ordinate) versus Time (minutes), (on the abcissa) on rectangular-grid graph paper.

8. The slope of the line in Step 7 is the oxygen uptake rate in mg D.O./liter/minute. Convert this rate to mg D.O./liter/hour.

9. Run total suspended and volatile suspended solids analyses on a portion of the sample.

10. Allow the approximately 200 mls of sample remaining from Step 3 to settle for 30 minutes; withdraw a portion of the settled supernatnat for BOD analysis.

11. Plot on rectangular-grid graph paper the O_2 uptake rate (mg/l/hr) (on the ordinate) from Step 8 versus time (hrs) (on the abscissa) elapsed since combining the raw sewage and RAS.

12. Plot on rectangular-grid graph paper the BOD remaining (mg/l) (on the ordinate) from Step 10 versus time (hrs) (on the abscissa) elapsed since combining the raw sewage and RAS.

The following methods were used to calculate the pounds of Oxygen required per pound of BOD removed:

A. Conventional Activated Sludge Process

On the graph of O_2 uptake rate versus time, draw a vertical line at the theoretical detention time of the aeration section. Planimeter the area between T_o and T (theoretical detention time) beneath the curve. Record this value as total mg O_2/liter used for the given detention time.

The initial calculated BOD is obtained as follows:

$$\text{Initial Calculated BOD} = \frac{\text{Influent Q x Influent BOD + RAS Q x RAS Supt. BOD}}{\text{Influent Q + RAS Q}}$$

The BOD removed is the difference between the initial calculated BOD, (mg/l) and the BOD of the FE at the theoretical detention time. The FE BOD value is obtained from the BOD remaining versus time curve for the chosen detention time.

The total O_2 used (mg O_2/l) divided by the total BOD removed (mg BOD/l) for the chosen detention time gives total milligrams (or pounds) O_2 required per milligram (or pound) of BOD removed.

B. Step Aeration Activated Sludge Process

As in the conventional process, the theoretical detention time for each zone of aeration is marked sequentially on the O_2 uptake rate versus time curve. The areas for each zone of aeration beneath the curve are planimetered. The areas determined are then multiplied by the respective volume for each zone of aeration to obtain a mass weight of O_2 used. The total O_2 requirement (mg) is obtained by summating the O_2 used in each zone.

The BOD removed for each zone of aeration is the value of the initial calculated BOD minus the FE BOD for that zone. The BOD removed times the respective volume of the zone of aeration were summated to obtain the total BOD (mg) removed for all zones. The pounds of O_2 required per pound of BOD removed was then obtained as for the conventional process.

C. Contact Stabilization Activated Sludge Process

A vertical line marking the theoretical detention time of the contact section is drawn on the O_2 uptake rate versus time curve for the contact and reaeration sections. The area beneath each curve was then planimetered and reported as mg O_2/l. The volume of each section is then multiplied by the respective mg O_2/l value; the mass of O_2 for each section is then summated to obtain the total O_2 used during the theoretical detention time of the contact section. The total BOD removed (mg/l) is the initial calculated BOD minus the FE BOD of the contact section at the theoretical detention time of the contact section. This value must be multiplied by the volume of the contact section to obtain the mass weight of BOD removed. The pounds of O_2 required per pound of BOD removed is then calculated the same as for the step aeration process.

D. Kraus Activated Sludge Process

The procedure to obtain pounds of O_2 required per pound of BOD removed is identical to that for the contact stabilization process; the nitrifying section was treated in the same manner as the reaeration section of the contact stabilization process.

SPECIAL STUDY - OXYGEN UPTAKE

Contact Stabilization

Control Process (B)

May 21, 1969

This study was conducted using a grab sample of fresh RAS placed in a 3-liter reactor identified as CS-Reaeration Section. Chlorine at the rate of 10.7 mg/l was added to the RAS to simulate actual conditions in the pilot plant.

A second reactor identified as CS-Contact Section, was set up using an R/Q value of 0.50. The actual volumes used were 3 liters of sludge from cell 5 (last cell of reaeration section) and 6 liters of primary effluent. To best represent the actual conditions in the pilot plant, nutrient addition was also included. (137 ml of nutrient solution was added to 6 liters of primary effluent. In actual operation the pilot plant added 1 ml of nutrient solution for each 44 ml forward flow of primary effluent.)

CS Reaeration Section

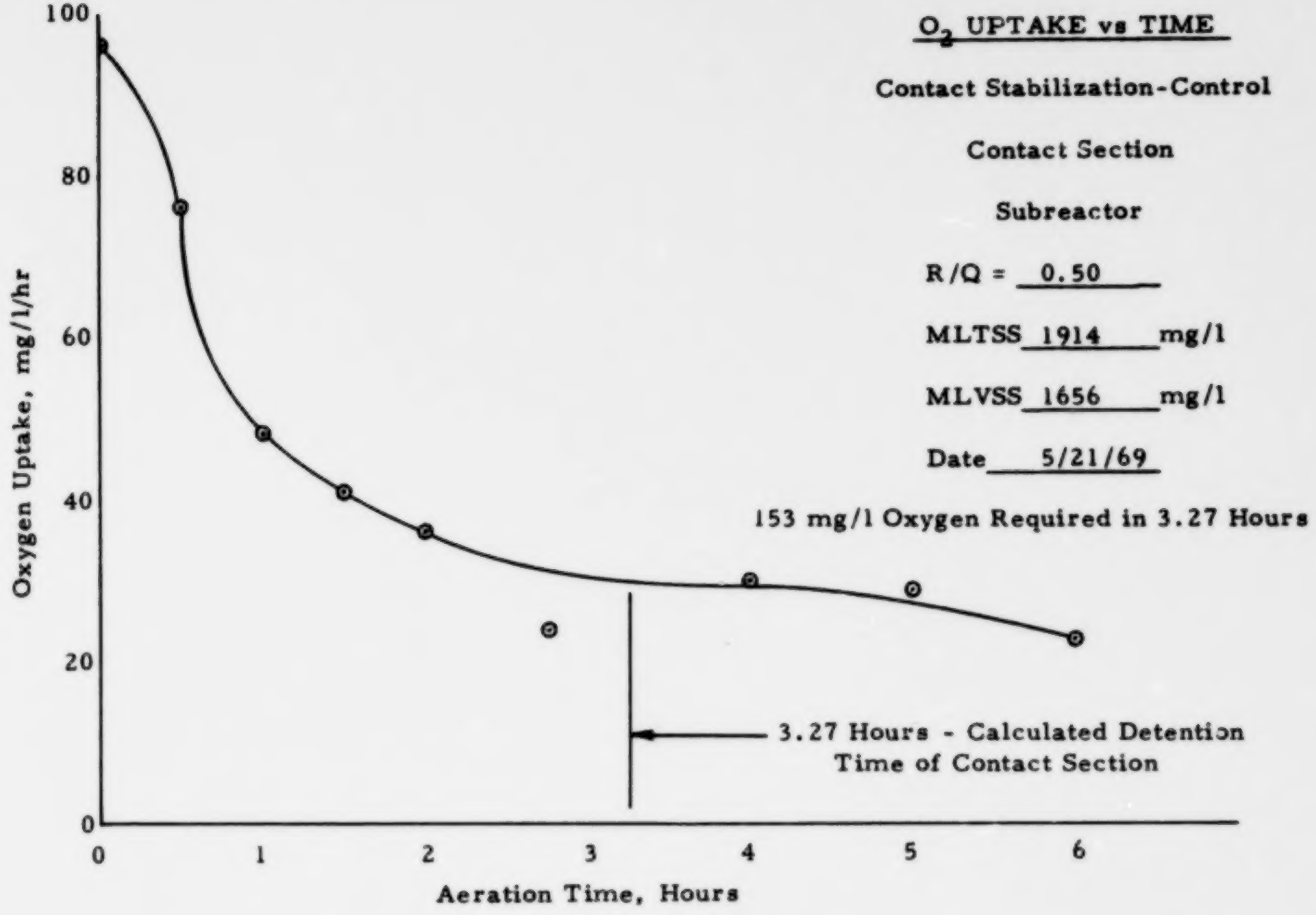
Time	Hours	MLTSS mg/l	MLVSS mg/l	% Vol.	O_2 Uptake mg/l/hr	O_2 Uptake mg O_2/g mlvss*/hr	BOD mg/l
09:15	0	11440	9608	84.0	81	8.4	
10:15	1				60	6.2	
11:15	2				60	6.2	
13:15	4				52	5.4	
15:15	6	11460	9696	84.6	45	4.7	

CS-Contact Section

Time	Hours	MLTSS mg/l	MLVSS mg/l	% Vol.	O_2 Uptake mg/l/hr	O_2 Uptake mg O_2/g mlvss*/hr	BOD mg/l
09:15	0	1712	1512	88.3	96	58.0	345
09:45	1/2				76	45.9	240
10:15	1				48	29.0	188
10:45	1-1/2				41	24.8	144
11:15	2				36	21.7	115
12:00	2-3/4				24	14.5	109
13:15	4				30	18.1	117
14:15	5				29	17.5	105
15:15	6	2116	1800	85.1	23	13.9	96
Primary Effluent							615
Cell 5		4832	4220	87.3		(Supernatant)	80

0.80 #O_2 Required/#BOD removed for 3.27 hr. detention time.

*Based on average of MLVSS determinations: 9.652 g for CS-reaeration sec.
1.656 g for CS-contact section



O_2 UPTAKE vs TIME

Contact Stabilization-Control

Contact Section

Subreactor

R/Q = 0.50

MLTSS 1914 mg/l

MLVSS 1656 mg/l

Date 5/21/69

153 mg/l Oxygen Required in 3.27 Hours

3.27 Hours - Calculated Detention Time of Contact Section

O_2 UPTAKE vs TIME

Contact Stabilization-Control

Reaeration Section

Subreactor

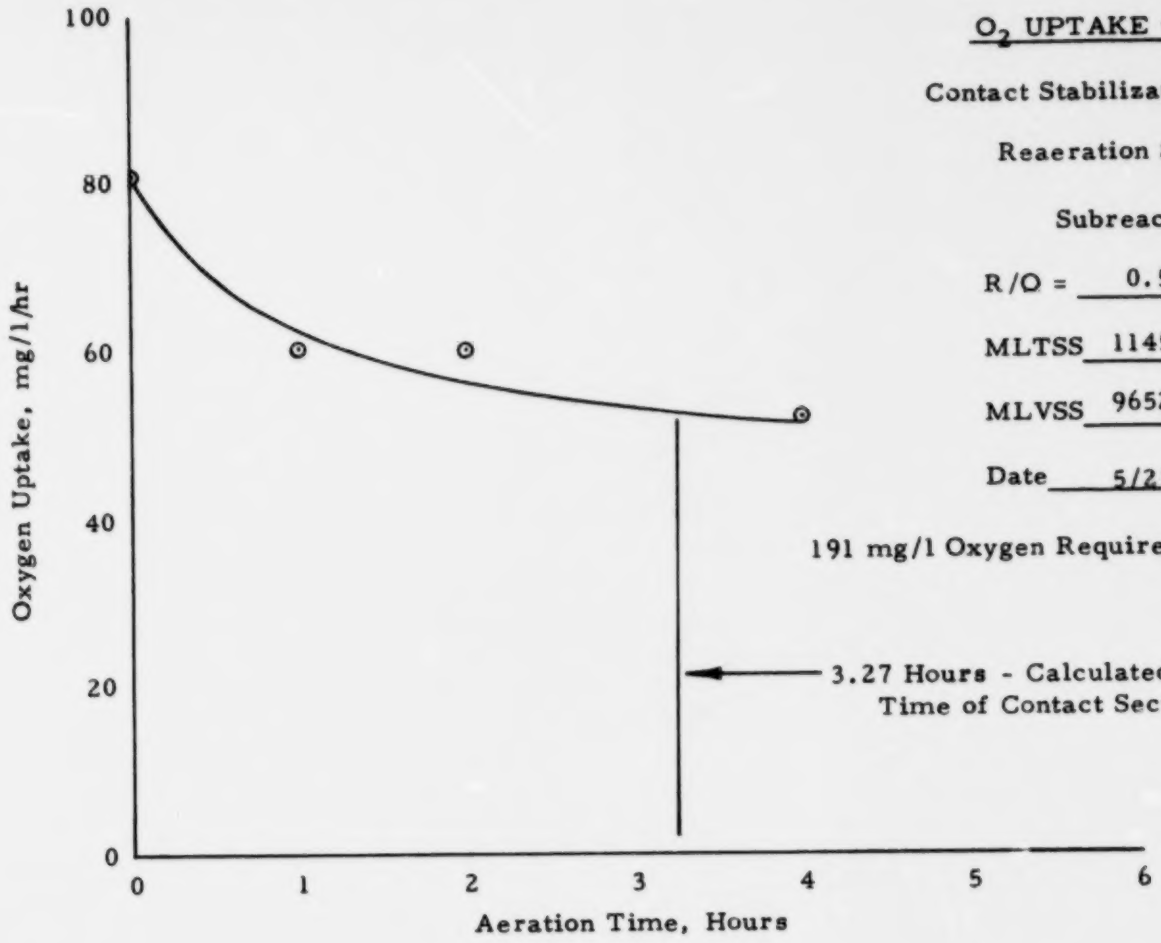
R/O = 0.50

MLTSS 11450 mg/l

MLVSS 9652 mg/l

Date 5/21/69

191 mg/l Oxygen Required in 3.27 Hours



3.27 Hours - Calculated Detention Time of Contact Section

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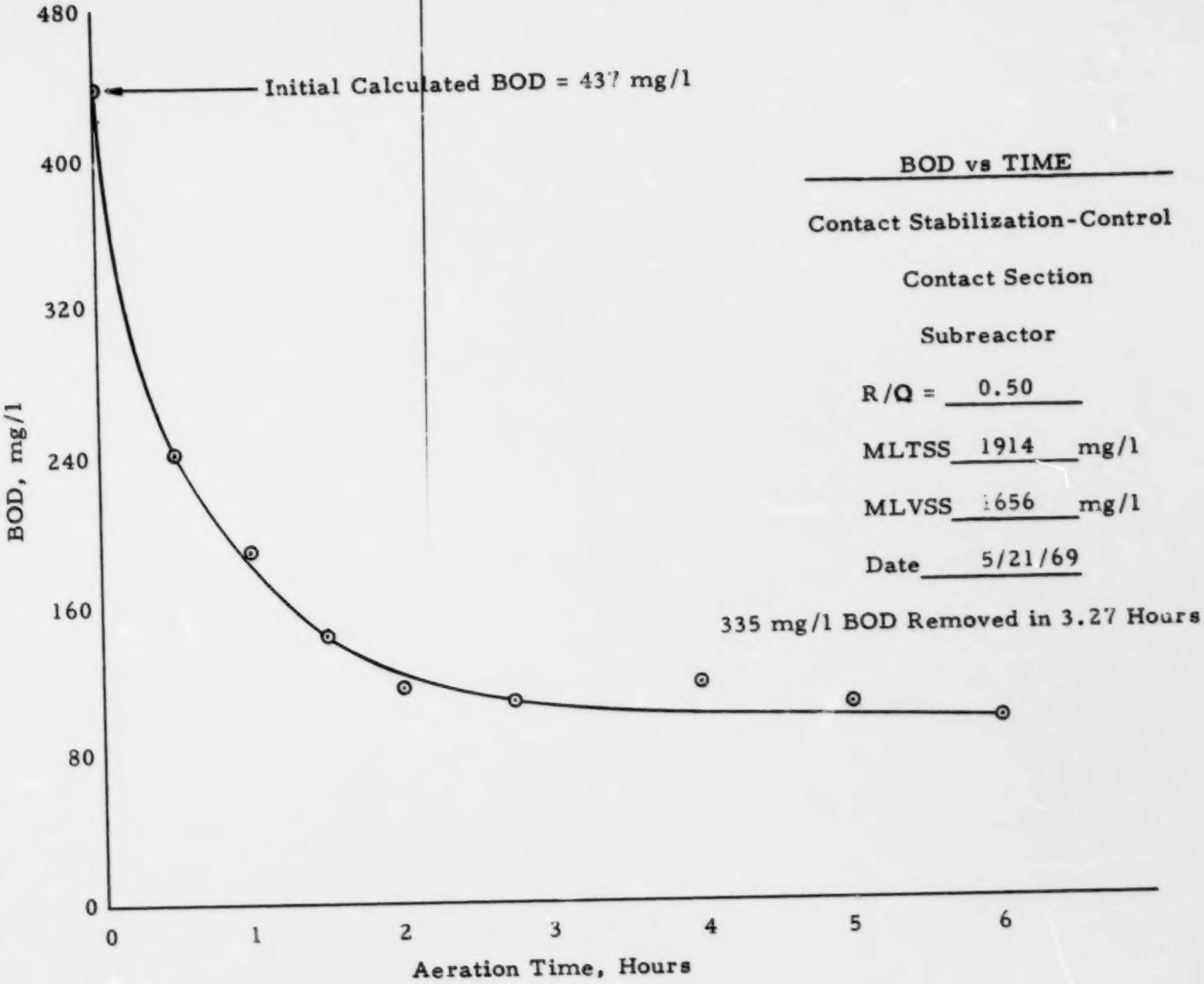

Initial Calculated BOD = 437 mg/l
BOD vs TIME
Contact Stabilization-Control
Contact Section
Subreactor
R/Q = 0.50
MLTSS 1914 mg/l
MLVSS 1656 mg/l
Date 5/21/69
335 mg/l BOD Removed in 3.27 Hours
BOD, mg/l
480
400
320
240
160
80
0
0
1
2
3
4
5
6
Aeration Time, Hours

SPECIAL STUDY - OXYGEN UPTAKE

Contact Stabilization

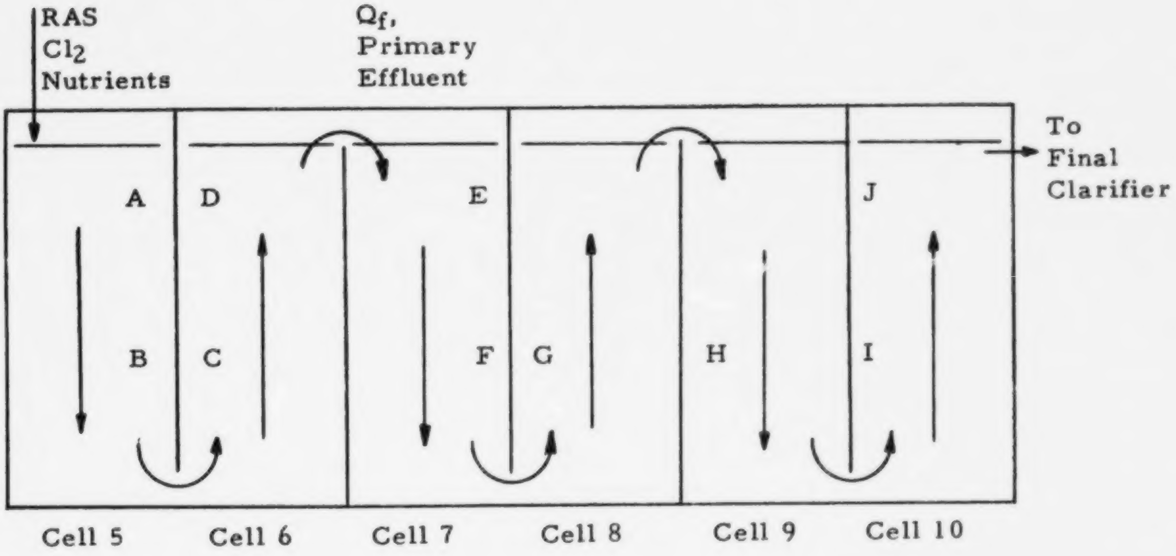
Process D

September 8, 1969

This study was conducted by grabbing samples directly from the pilot plant reaeration and contact section cells. In an attempt to insure the use of accurate detention time in plotting the curves of "O_2 Uptake vs. Time", samples were taken from the initial point of entry to the cells and from mid-depth in the cells. The results tend to show that, due to thorough mixing within the cells, the values for the mid-cell analyses would be the best in plotting the various curves.

The flows of RAS, nutrient addition and chlorine addition into the pilot plant were measured at the time of the study. The Q_f value and the mixed liquor solids determinations were taken from the daily calculations. Cell and total detention times were based upon the flow data for the pilot plant at the time the tests were conducted.

The location of the samples, A-J, are shown in the sketch below.


RAS
Cl_2
Nutrients
Q_f,
Primary
Effluent
To
Final
Clarifier
A
D
E
J
B
C
F
G
H
I
Cell 5
Cell 6
Cell 7
Cell 8
Cell 9
Cell 10

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SPECIAL STUDY - OXYGEN UPTAKE

PROCESS D

September 8, 1969

	REAERATION		CONTACT			
	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9	Cell 10
Sample Time	12:30	12:45	1:10	1:20	1:30	1:40
Cell Detention Time, Hours	1.82	1.82	0.60	0.60	0.60	0.60
Total Detention Time, Hours	1.82	3.64	0.60	1.20	1.80	2.40
MLTSS		10140				3728
MLVSS		8924				3368
% Volatile		88.0				90.3
O_2 Uptake - Mid Cell Value; mg/l/hr	60	48	75	54	42	39
BOD - Mid Cell Value; mg/l			102	68	53	42

Q_f - 4552 L/D   Nutrient Solution - 67.7 L/D

RAS- 2131 L/D Cl_2 Solution - 50.4 L/D

Based on attached data, 0.67 pounds of O_2 are required (total amount for reaeration plus contact sections) per pound of BOD removed in the Contact section.

Note: Cells 1-4 were not being used at the time of this study.

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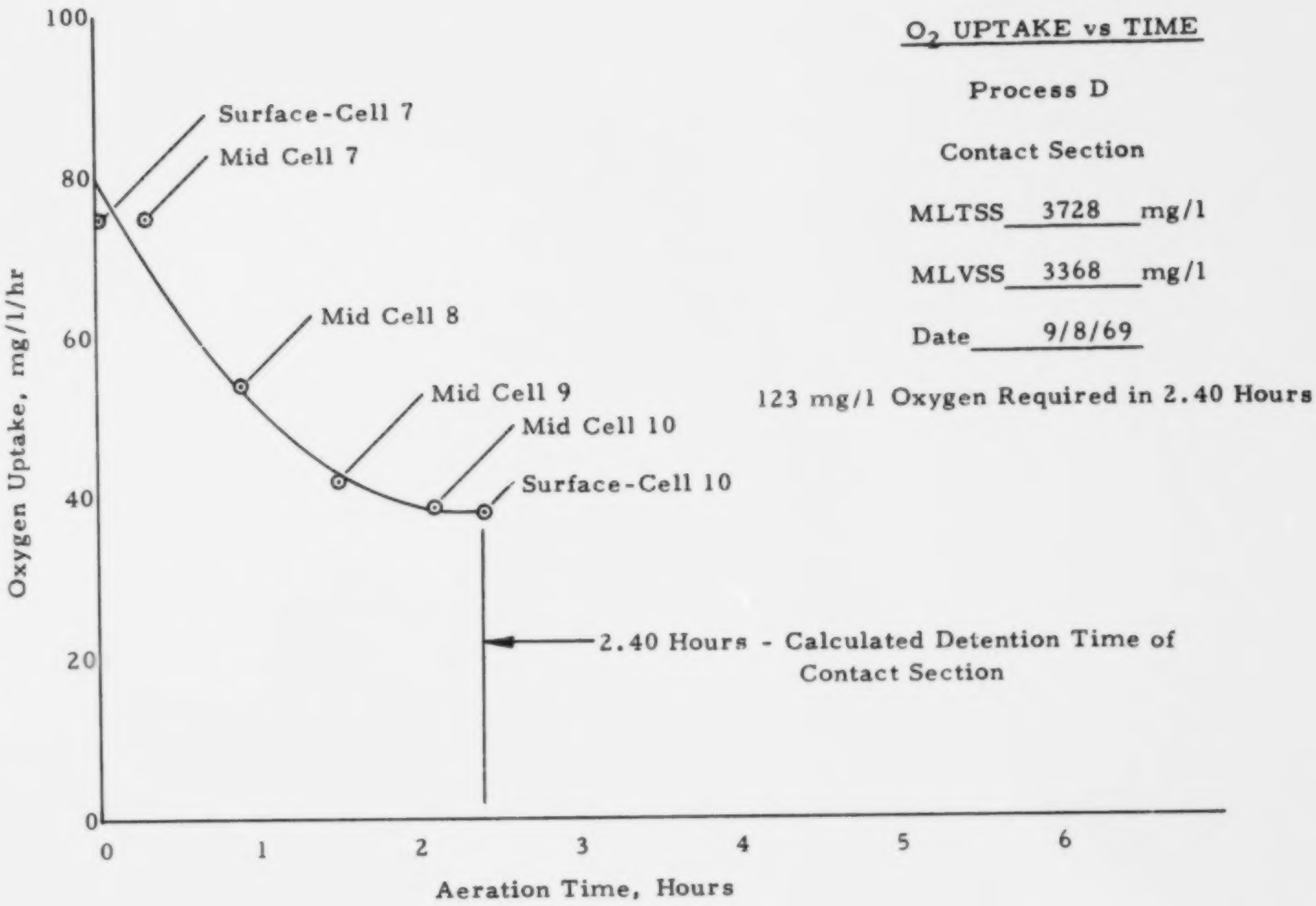


O_2 UPTAKE vs TIME

Process D

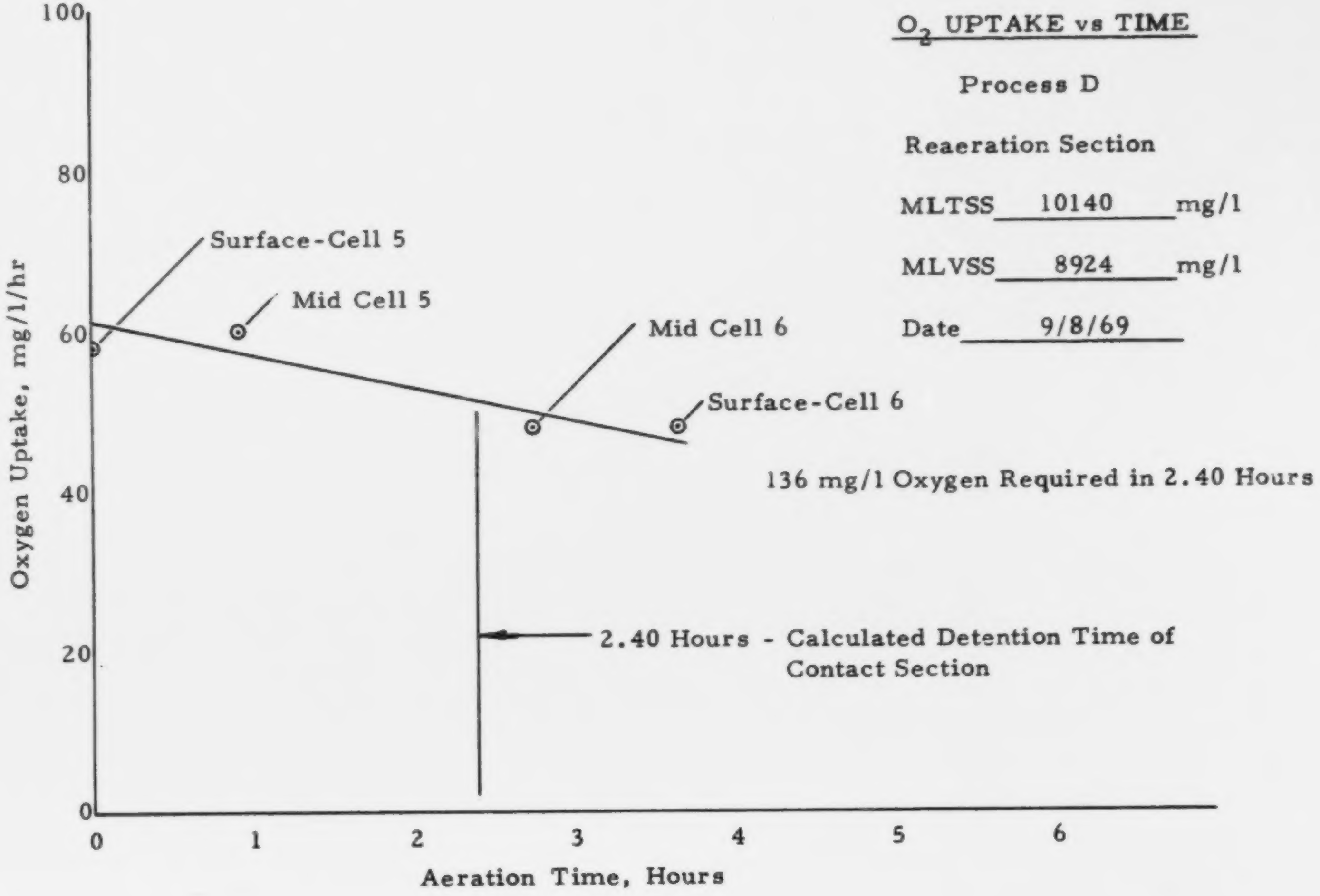
Contact Section

MLTSS 3728 mg/l

MLVSS 3368 mg/l

Date 9/8/69

123 mg/l Oxygen Required in 2.40 Hours



O_2 UPTAKE vs TIME

Process D

Reaeration Section

MLTSS 10140 mg/l

MLVSS 8924 mg/l

Date 9/8/69

136 mg/l Oxygen Required in 2.40 Hours

2.40 Hours - Calculated Detention Time of Contact Section

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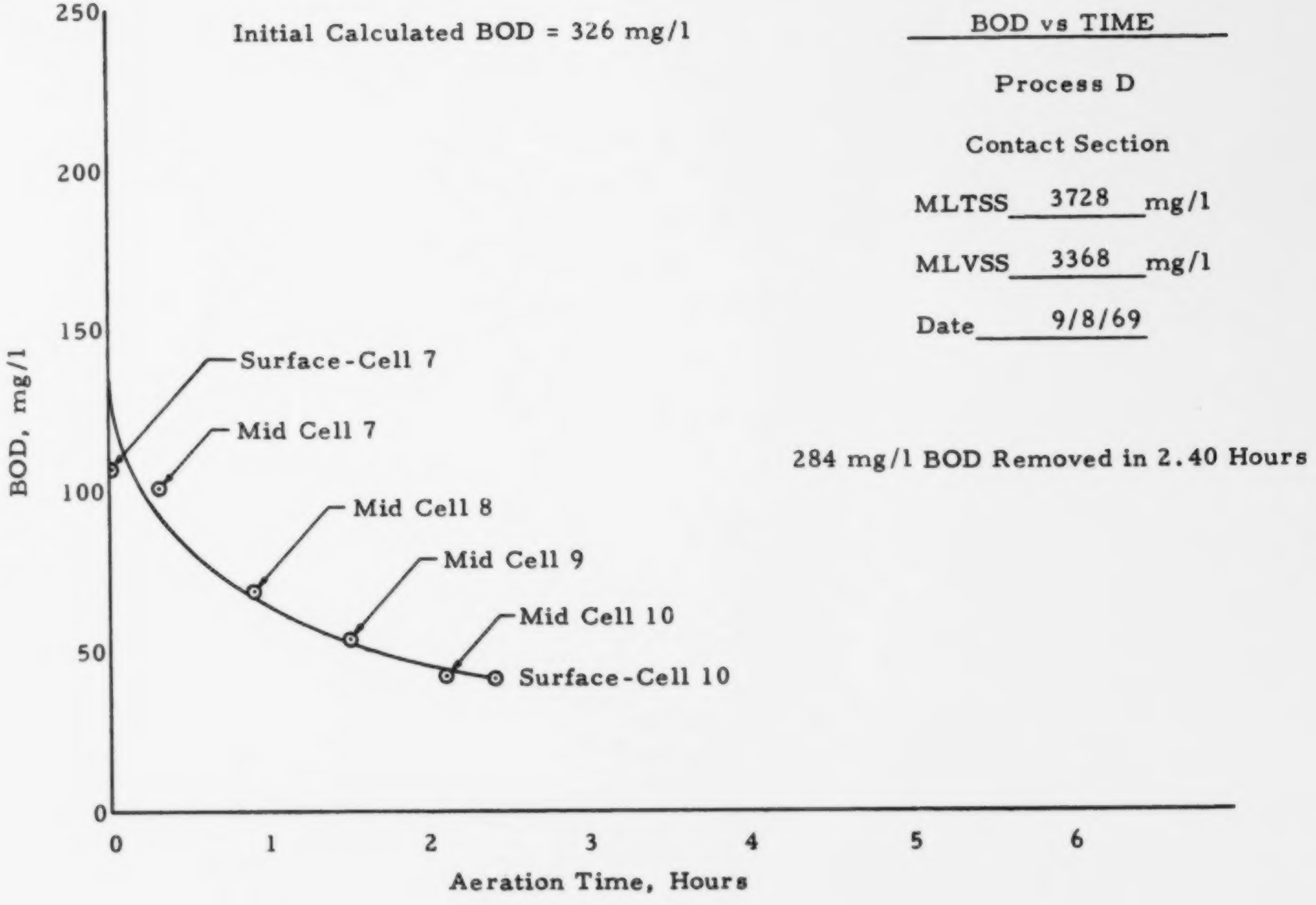

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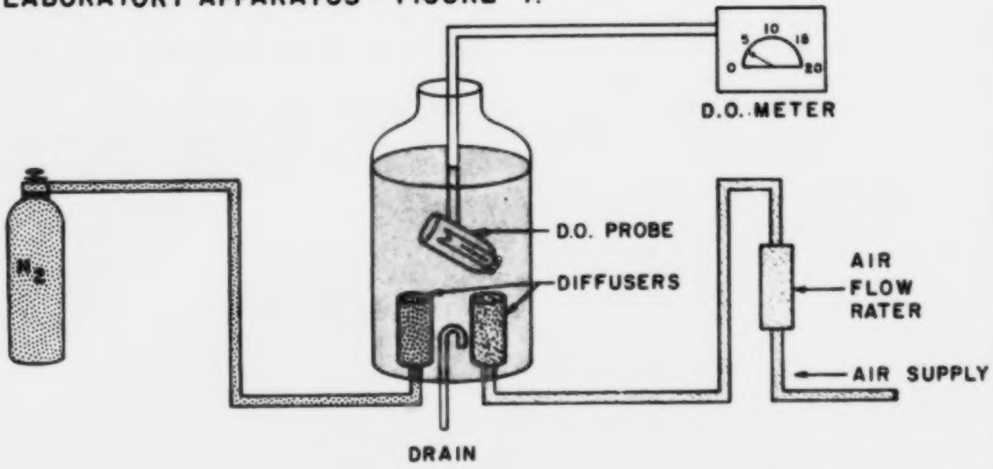
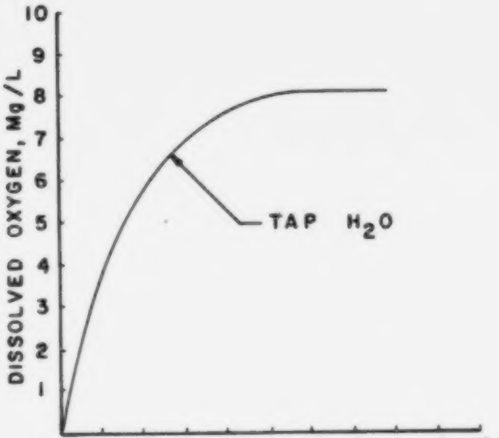
O_2 TRANSFER PROCEDURE

LABORATORY APPARATUS - FIGURE 1.


0
5
10
15
20
D.O. METER
N_2
D.O. PROBE
DIFFUSERS
AIR
FLOW
RATER
AIR SUPPLY
DRAIN

1. Place tap H_2O (temperature adjusted to that of the sample to be run) in container (approximately 2 liter cylinder).
2. Strip any O_2 present in H_2O with N_2 gas.
3. Aerate at a constant air flow rate.
4. Measure D.O. at various time intervals.
5. Plot a curve of D.O. vs. aeration time on 10 x 10 rectangular graph paper.

FIGURE 2.



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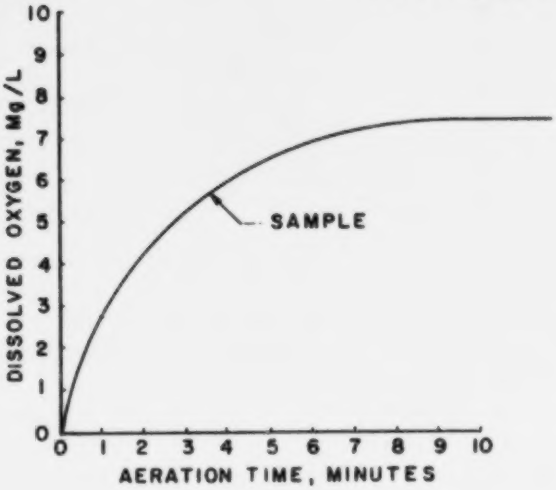
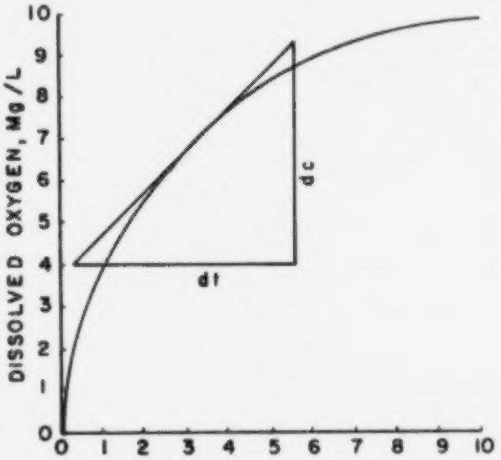
6. Drain H_2O (Do not change position of D.O. probe or diffusers.)
7. Place sample in container.
8. Strip O_2 with N_2 gas.
9. Aerate at the same air flow rate as used with the tap H_2O.
10. Measure D.O. at various time intervals.
11. Plot a curve of D.O. vs. aeration time on 10 x 10 rectangular graph paper.

FIGURE 3.



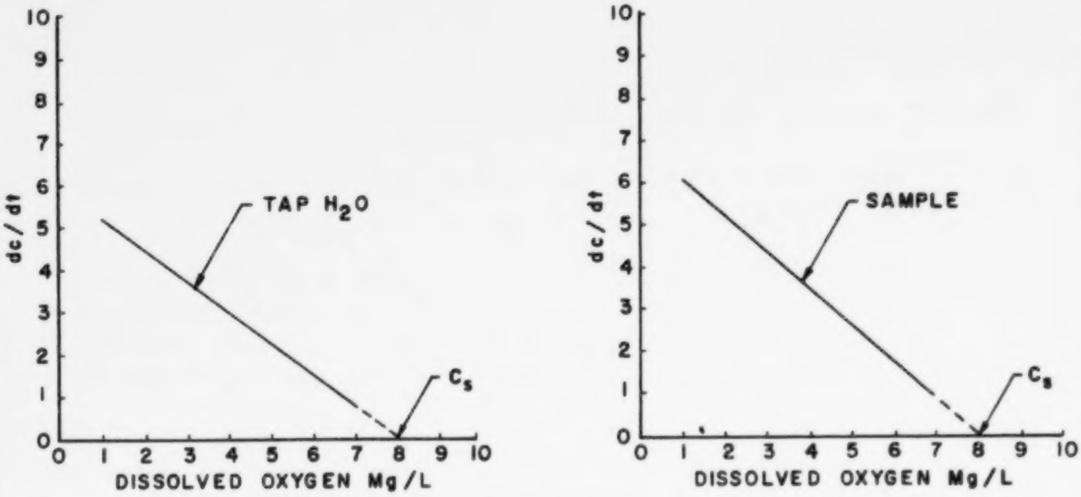
12. Determine the slopes of tangents drawn to the curves at several points along the curve, (avoid using the ends of the curves).

FIGURE 4.



13. Plot dc/dt vs. D.O. concentration for the tap H_2O and for the waste sample.

Figure 5.



14. Determine the slope of the lines plotted in Figure 5.
15. Alpha* equals the slope of the waste sample curve (K_1A-Waste) divided by the slope of the tap H_2O curve (K_1A-Tap Water).
16. By extending the line plotted in Figure 5 until it intersects the axis of D.O. concentration, the O_2 saturation value of the sample can be determined.

17. Beta is the O_2 saturation value of the Waste (C_s-Waste) divided by O_2 saturation value of the tap H_2O (C_s-Tap Water).

$$\text{*Alpha} = \frac{K_1A \text{ Waste}}{K_1A \text{ Tap Water}}$$

SULFIDE ANALYSES

Equipment: Model 404 Orion Specific Ion Meter; Sulfide Probe Model 94-16; Orion Double Junction Reference Electrode Model 90-02.

The calibration curve for the measurement of sulfide ion is a plot of millivolt reading vs. the log of the activity of the sulfide ion in moles/liter. A 20 x 20 cycle rectangular graph paper is used for this plot. A low point and a high point are determined for this graph and a straight line is then plotted through the two points.

The low point for the graph is found by the following procedure:

1. Saturate a 0.1 Molar HCl solution with H_2S gas for approximately 10 minutes.

2. With the Orion sulfide probe and double junction reference electrode installed on the Model 404 Orion Specific Ion meter, and the control knob placed in the millivolt mode, insert the probes in the HCl-H_2S solution and read and record the millivolt reading.

3. The known activity for this solution is 1.8×10^{-19} moles/liter. Knowing the millivolt reading and the activity for this solution, the low point can then be plotted on the graph.

The high calibration point is found as follows:

4. Make a .1 Molar solution of $Na_2S \cdot 9H_2O$ in H_2O rather than in 1 Molar NaOH as specified in the instruction book.

5. Dilute the solution from Step 4 accurately to 1:1 with a buffer solution to lower the pH to between 7.6 and 8.0. If necessary, a few drops of concentrated HCl may also be added to bring the pH to the desired range.

6. Place the solution from Step 5 in a beaker and insert the sulfide reference probes (see Step 2). Read and record the millivolt reading. The millivolt reading should be approximately 680-690 millivolts. Measure the pH of the solution.

7. To determine the total sulfide concentration (C_t), titrate 25 ml of the solution from Step 5 with 0.1 Molar silver nitrate ($AgNO_3$) using the sulfide probe and meter to determine the end point by

titrating through zero millivolts. The resulting concentration of the sodium sulfide should be about .05 Molar.

8. The formula, $C_t = f \times A_{s^=}$, can now be used to obtain the value for $A_{s^=}$. The value for C_t is obtained in Step 7. The value for f is a function of the pH of the solution and can be obtained from a chart in a sulfide probe instruction manual. Knowing C_t and f, the value for $A_{s^=}$ can be determined. Having the value of $A_{s^=}$ and the millivolt reading for the given solution, this point can then be plotted on the calibration curve.

9. Draw a straight line between the two points on the graph. The slope of the line should be such that there is about 29.6 millivolt change for a tenfold change in concentration.

To measure sulfides in an unknown solution;

1. Determine millivolt reading of solution.
2. Measure pH of solution and obtain value for "f".
3. Obtain $A_{s^=}$ from calibration curve.
4. Knowing f and $A_{s^=}$ calculate C_t.
   $C_t = f \times A_{s^=}$

MICROBIOLOGICAL ANALYSES

Microbiological analyses on activated sludge samples were conducted routinely every two days unless some unusual condition required closer and more frequent observations. Grab samples were taken from Cell 10 of each of the four plants for these analyses. Grab samples of mill wastes were analyzed about once a month.

All analyses were made using an American Optical Series 10 Phasestar microscope equipped with a Polaroid camera. Photographs of Cell 10 observations were taken once a week. In addition, any unusual or excessive condition was photographed at the time of occurrence. Maximum magnification with this microscope and 20X eyepiece was 2000X, with a maximum Polaroid print magnification of 1500X.

All samples were first observed on low power (200X) for filament extent, floc dispension, and bridging of floc. The presence of higher biological forms and of non-biological forms was noted. Samples were then observed on high power (900X). The types of biological life were reported and any filaments were examined for presence of granules.

If the number of filaments was sufficiently great, filament identification was attempted according to the procedure developed by Dr. Farquhar(16).

The microphotograph form is shown on the next page.

MICROPHOTOGRAPH FORM

Sample __________ Picture No. __________ Date __________

Magnif. 75 150 338 750

Trans. Set 4.5 5.0 5.5 6.5 7.5

Expos. Time 1/1 1/2 1/5 1/10 1/25 1/50 1/125

Mount — Wet, Dry; Dry — Air, Heat; Coverglass, Yes No

Stain — Yes No: 1 2 3 4 5 6 7

Phase — Yes No; Contrast — Bright, Dark

Objective 10x 20x 45x 100x

Condenser A B C D O

Illuminator Filter — Yes, No; Others — Yes, No

REMARKS:

Initials

FINAL CLARIFICATION-LABORATORY PROCEDURE - PHASE II

The samples used for the final clarification studies during Phase II were Cell 10 (last aeration cell) mixed liquor (at the existing concentration) from each pilot plant.

The equipment utilized was a 3-1/2 inch internal diameter x 12-feet sidewater-depth clear acrylic settling tube. The column contained a mechanical stirrer operating at a peripheral speed of about 1.0 feet per minute. An acrylic block was used as the base for the column and was supported above the floor by an angle iron frame with adjustable legs. A pipe tee was tapped into the bottom of the acrylic block to permit dual valving for filling and draining the column. This bottom-fill technique was employed to minimize the formation of air bubbles and to keep the column contents homogeneously mixed until the column was filled.

The position of the solids-liquid interface was recorded every 5 minutes for the first half hour, every 10 minutes for the next half hour, every 15 minutes for the next three hours, and every 30-60 minutes thereafter until there was no change in the interface height for at least three successive readings or until the test was arbitrarily stopped. The resulting settling curve was analyzed by the Kynch Method to determine the time of concentration (T_c) to obtain a 1.0% sludge underflow concentration. Based upon the initial portion of the settling curve, corresponding clarification rates (C.R.) were calculated in terms of gallons per day per square foot of surface area.

This column was also used for the gravity settling column tests discussed in the section of this report entitled, "Primary Clarification". Removable taps, which projected 1/2 the radius into the tube, were inserted at the 2, 4, 6, 8, 10 and 12-feet levels above the bottom of the column. The tube was slowly filled from the bottom with the sample. The taps were sampled sequentially from the top to the bottom each 15 minute interval. for 90 minutes; approximately 50 mls of liquid were first wasted from each tap to insure that a representative sample was obtained. Based upon the initial and sequential total suspended solids analyses, the percent removal at each depth for each time period was calculated.

GRAVITY THICKENING-LABORATORY PROCEDURE - PHASE III, IV

During Phase III and IV of the research project, fresh WAS and combined fresh WAS and primary clarifier sludge were used as sludge sources for the gravity thickening tests. During Phase III the samples were used as obtained; during Phase IV both undiluted and diluted (with final effluent) samples were used.

The equipment utilized consisted of one-liter graduated glass cylinders equipped with mechanical stirring mechanisms which operated at a peripheral speed of approximately 0.05 fpm. The pickets were three small-diameter rods, extending the full length of the cylinder, which were rigidly positioned in a triangular pattern approximately one inch on a side.

Solids-liquid interface readings were taken every 5 minutes for the first half hour, every 10 minutes for the next half hour and every 30 minutes for each hour thereafter until there was no change in the interface height for at least three successive readings, or until the test was arbitrarily stopped. These data were plotted on rectangular graph paper and the resulting curves were analyzed to obtain the desired design parameters.

AIR FLOTATION-LABORATORY PROCEDURE - PHASE II, III, IV

All air flotation tests were conducted according to test procedures developed by Rex Chainbelt, Inc. The equipment consisted of a small clear acrylic pressure cylinder and one-liter graduated cylinders.

For Phase II, the air flotation tests were run on diluted samples of Cell 10 mixed liquor and WAS respectively, rather than utilizing the existing solids concentration of the given sample. The sample was diluted with final effluent to approximately the same concentration as the lowest sample concentration of the four pilot plants. For Phase III and IV, the samples were used as obtained and were not diluted with final effluent.

The solids-liquid interface was plotted versus time to determine the point at which compaction of the floating solids blanket began. This compaction point was used to determine the rate of ascent (or rise rate) in feet/minute.

Two flotation-thickening parameters for each pilot plant sample, the rate of ascent and the calculated float concentration, were each ranked 1, 2, 3, or 4 for the four samples. These values were then summated to yield a composite ranked value for each pilot plant.

SLUDGE PRODUCTION CALCULATIONS - PHASE II, III, IV

Sludge production calculations were based on the last 7 days of data for each statistical experimental design condition during Phase II. Seven-day intervals were also used during Phase III. Sludge production calculations during Phase IV were based on intervals ranging from 15 to 27 days.

Factors considered were:

1. The total amount of WAS (TSS, grams) generated during the study period.
2. The discharge of solids (TSS, grams) from the process, via the final effluent, during the study period.
3. The change in inventory of solids (TSS, grams) under aeration between the first and last day of the study period.
4. The change in inventory of solids (TSS, grams) in the final clarifier between the first and last day of the study period.

The equation is as follows:

Total Sludge Production =

$$\text{WAS} + \text{TSS in FE} + \Delta\text{TSS in Aeration Tank} + \Delta\ \text{TSS in FC.}$$

Seven-day averages of primary effluent and final effluent BOD were used during Phase II to determine the grams of BOD removed during the interval. Both filtered and unfiltered BOD removals were determined and corresponding sludge production rates were calculated. (Filtered BOD values were obtained using Whatman No. 5 filter paper.) A summation of daily BOD removal values was used for Phase III and IV solids production rate calculations.

04 69 PRIMARY CLARIFIER FORM A1

		FLOW DATA	LITER / DAY	MILLS				INFLUENT				
DAY	DATE	1	2	3	4	MSD	TOTAL	PH	TSS	VSS	BOD	S=
	01	1853	1853	3892	0926	0004819	13343	6.5	252	240	0615	
	02	1853	1853	3892	0926	0005088	13612	6.8	212	144	0650	
	03	1853	1853	3892	0926	0005205	13729	6.6	248	160	0550	
	04	1853	1853	3892	0926	0006208	14732	6.4	176	156	0510	
	05	1853	1853	3892	0926	0005731	14255	6.4	492	480	0521	
	06	1853	1853	3892	0926	0005830	14354	6.6	116	096	0561	
	07	1853	1853	3892	0926	0008415	16939	6.7	188	160	0439	
	08	1853	1853	3892	0926	0010482	19006	6.7	192	172	0370	
	09	1853	1853	3892	0926	0010130	18654	6.9	184		0535	
	10	1853	1853	3892	0926	0008919	17443	6.8	124		0495	
	11	1853	1853	3892	0926	0008843	17367	6.8	196	180	0645	
	12	1853	1853	3892	0926	0008022	16546	6.8	184	160	0533	
	13	1853	1853	3892	0926	0006610	15134	6.7	092	080	0606	
	14	1853	1853	3892	0926	0008044	16568	6.7	200	136	0584	
	15	1853	1853	3892	0926	0008030	16554	6.8	204	156	0530	
	16	1699	1776	3892	0926	0007363	15656	6.7	184	156	0490	
	17	1621	1853	3487	0830	0007468	15259	6.8	216		0525	
	18	1853	1853	3892	0926	0006981	15505	6.7	180	140	0510	
	19	1853	1853	3892	0926	0007582	16106	6.7	132	120	0578	
	20	1853	1853	3892	0926	0006935	15459	6.8	136	124	0572	
	21	1853	1853	3892	0926	0006564	15088	6.4	272	192	0593	
	22	1853	1853	3892	0926	0007745	16269	6.7	204	196	0590	
	23	1853	1853	3892	0926	0011152	19676	6.8	308	224	1230	
	24	1853	1853	3892	0926	0011466	19990	6.7	116	064	0515	
	25	1853	1853	3892	0926	0007495	16019	6.8	252	220	0500	
	26	1853	1853	3892	0926	0009513	18037	6.7	192	192	0476	
	27	1853	1853	3892	0926	0009933	18457	6.6	168	144	0442	
	28	1853	1853	3892	0926	0010209	18733	6.8	252	212	0458	
	29	1853	1853	3892	0926	0009081	17605	6.7	200	180	0520	
	30	1853	1853	3892	0926	0009623	18147	6.8	244	212	0725	
TOTAL		055204	055513	0116355	027684	0239486	00494242	200.9	06116	04696	016868	
AVG		1840	1850	3879	923	7983	16475	6.7	204	174	562	.00
MAX		1853	1853	3892	0926	0011466	19990	6.9	492	480	1230	
MIN		1621	1776	3487	0830	0004819	13343	6.4	092	064	0370	

04 69 PRIMARY CLARIFIER FORM A2

		EFFLUENT			TSS P/CNT		BOD P/CNT	EFFLUENT		BOD	COLOR	
DAY	DATE	PH	TSS	VSS	RED	BOD	RED	COD	TC	TC	UNITS	S=
	01	6.3	064		74.6	630		1728	570	1.11		
	02	6.9	132	100	37.7	620	4.6	1681	540	1.15		
	03	6.7	240	160	3.2	545	.9	1594	510	1.07		
	04	6.3	136	128	22.7	525		1464	470	1.12		
	05	6.4	152	148	69.1	572		1446	510	1.12		
	06	6.4	116	112	.0	538	4.1	1430	510	1.05		
	07	6.7	112	104	40.4	417	5.0	1267	470	.89		
	08	6.7	136	136	29.2	380		1099	420	.90		
	09	6.8	120		34.8	435	18.7	1000	410	1.06		
	10	6.9	112		9.7	570		1199	460	1.24		
	11	6.8	124	120	36.7	540	16.3	1356	490	1.10		
	12	6.9	128	116	30.4	482	9.6	1432	505	.95		
	13	6.7	080	072	13.0	487	19.6	1470	515	.95		
	14	6.9	152	108	24.0	507	13.2	1417	490	1.03		
	15	6.9	160	128	21.6	435	17.9	1426	450	.97		
	16	6.9	140	108	23.9	420	14.3	1652	470	.89		
	17	6.7	100		53.7	495	5.7	1280	460	1.08		
	18	6.8	140	096	22.2	400	21.6	1402	495	.81	318	
	19	6.7	140	104		567	1.9	1417	500	1.13		
	20	6.8	112	080	17.6	493	13.8	1424	460	1.07		
	21	6.5	176	132	35.3	530	10.6	1591	535	.99	318	
	22	6.8	124	112	39.2	535	9.3	1560	535	1.00		
	23	6.6	168	120	45.5	540	56.1	1433	490	1.10		
	24	6.8	088	040	24.1	385	25.2	1216	450	.86		
	25	6.9	184	044	27.0	470	6.0	1285	455	1.03		
	26	6.8	112		41.7	459	3.6	1293	440	1.04		
	27	6.7	120	092	28.6	408	7.7	1245	445	.92		
	28	6.8	172	152	31.7	408	10.9	1245	445	.92		
	29	6.8	116	104	42.0	495	4.8	1282	480	1.03		
	30	6.8	168	128	31.1	505	30.3	1339	460	1.10	323	
TOTAL		201.7	04024	02744		14793		041673	14440	30.68	00959	
AVG		6.7	00134	00110	34.3	00493	12.3	001389	00481	1.02	00320	.00
MAX		6.9	240	160	74.6	630	56.1	1728	570	1.24	323	
MIN		6.3	064	040	.0	380	.9	1000	410	.81	318	

04 69 AERATION TANK SOLIDS PROCESS A FORM B1

		REAERATION SEC.			CONTACT SEC.			RETURN WASTE	AND SLUDGE	
DAY	DATE	TSS	VSS	P/CNT	TSS	VSS	P/CNT	TSS	VSS	P/CNT
	01	08704	07288	83.7	5388	4604	85.4	09056	07652	84.5
	02	08860	07468	84.3	5444	4584	84.2	08516	07332	86.1
	03	08568	07192	83.9	5424	4640	85.5	09436	08026	85.1
	04	08904	07704	85.8	5128	4388	85.6	09628	08160	84.8
	05	09604	08196	85.3	5216	4448	85.3	09156	07856	85.8
	06	09278	07946	85.6	5056	4374	86.5	09624	08344	86.7
	07	08952	07696	86.0	4896	4300	87.8	10096	08836	87.5
	08	10036	08720	86.9	4880	4180	85.7	10208	09004	87.5
	09	10156	08756	86.2	4684	4092	87.4	09560	08396	87.8
	10	09728	08392	86.3	4772	4136	86.7	09508	08412	87.7
	11	09428	08312	88.2	4964	4172	84.0	09332	08328	89.2
	12	09508	08292	87.2	4704	4228	88.2	09752	08566	87.9
	13	09120	07952	87.2	5132	4530	88.3	09824	08576	86.8
	14	08732	07612	87.2	5468	4832	88.4	09896	08484	85.7
	15	10308	09080	88.1	5236	4628	88.4	10748	09512	88.5
	16	09680	08684	89.7	5064	4504	88.9	10460	09232	88.3
	17	10340	09144	88.4	4652	4084	87.4	09912	08732	88.1
	18	10100	08768	86.8	4592	4060	88.4	10148	08900	87.7
	19	10596	09028	85.2	4728	4026	85.1	10808	09500	87.9
	20	10376	09038	87.1	4952	4208	86.6	11046	09760	88.4
	21	10156	09048	89.1	5176	4552	87.9	11204	10020	88.8
	22	11248	09824	87.3	5188	4620	89.1	11756	10376	88.3
	23	12524	11012	87.9	4752	4184	88.0	13164	11524	87.5
	24	13632	11680	87.0	4636	4064	87.7	12112	10620	87.7
	25	11688	10140	86.8	4526	3920	86.7	11472	10048	87.6
	26	11260	09704	86.2	4724	4160	88.0	11172	09752	87.3
	27	10692	09188	85.9	4296	3718	86.7	10048	08718	86.8
	28	10124	08672	85.7	3852	3276	85.0	08924	07684	86.1
	29	09376	08244	87.9	5824	4964	85.2	09368	08112	86.6
	30	09672	08276	85.6	4208	3736	88.8	10692	09108	85.2
TOTAL		301230	261056		147636	128264		306868	267526	
AVG		010041	008702	86.7	004921	004275	86.9	010229	008918	87.2
MAX		13632	11680	89.7	5824	4964	89.1	13164	11524	89.2
MIN		08568	07192	83.7	3852	3276	84.0	08516	07332	84.5

04 69 AERATION TANK SOLIDS PROCESS A FORM B2

		DIGESTER	SUPERNATANT					SET SL VOLUME				F/M RATIO	
DAY	DATE	TSS	VSS	BOD	L/D ADDED	GRAMS TSS ADDED	DS-TSS PF TSS	10 MIN	30 MIN	30 MIN SVI	CLAR. SLUDGE LEVEL	TC VSS	BOD VSS
	01							0980	0910	00169	45	.34	.37
	02							0960	0890	00163	44	.32	.37
	03							0950	0850	00157	41	.31	.33
	04							0930	0830	00162	41	.31	.34
	05							0950	0780	00150	41	.31	.35
	06										41	.32	.34
	07							0930	0760	00155	41	.36	.32
	08							0880	0700	00143	00	.34	.31
	09							0900	0680	00145	00	.35	.35
	10							0900	0620	00130	00	.35	.44
	11							0850	0470	00095	00	.36	.41
	12							0800	0620	00124	00	.37	.35
	13										00	.34	.32
	14							0800	0500	00091	00	.34	.36
	15							0770	0440	00103	00	.30	.29
	16							0500	0350	00069	00	.31	.27
	17							0450	0300	00064	00	.30	.32
	18							0550	0320	00070	00	.33	.27
	19							0510	0300	00063	00	.35	.30
	20										00	.30	.32
	21							0520	0380	00075	00	.33	.32
	22							0470	0360	00069	00	.34	.34
	23							0450	0280	00059	00	.37	.40
	24							0350	0260	00056	00	.33	.29
	25							0450	0250	00055	00	.30	.31
	26							0450	0300	00063	00	.32	.33
	27										00	.36	.33
	28							0310	0210	00055	00	.40	.37
	29							0530	0290	00050	00	.34	.35
	30							0480	0250	00059	00	.39	.43
TOTAL					.		.	17640	13000	02597	0294	10.09	[illegible]
AVG		000000	000000	00000	.0	000000	.0	00678	00500	00100	0010	.34	.34
MAX					.		.	0980	0910	00169	45	.40	.44
MIN								0310	0210	00050	00	.30	.27

04 69 SUPPLEMENTAL OPERATING DATA PROCESS A FORM C1

		FEED BYPASS	Q ACT	RAS ACT	R/Q	WAS ACT	SOL. WASTED GRAMS / DAY		F.C. TSS LOAD
DAY	DATE	L/D	L/D	L/D	RATIO	L/D	TSS	VSS	LB/SF/D
	01	0000	003336	3802	1.14	22.7	000206	000174	27.0
	02	0000	003403	3715	1.09	87.1	000742	000639	27.2
	03	0000	003432	3456	1.01	75.7	000714	000608	26.4
	04	0000	003683	3283	.89	56.8	000547	000463	25.1
	05	0000	003584	3024	.85	60.6	000555	000476	24.1
	06	0000	003589	3024	.84	45.4	000437	000379	23.5
	07	0000	004235	3456	.82	36.3	000306	000268	26.4
	08	0000	004752	3226	.68	98.4	001012	000886	27.5
	09	0000	004664	3456	.74	68.1	000651	000572	26.7
	10	0000	004361	3456	.79	49.2	000472	000414	26.2
	11	0000	004342	3398	.78	79.5	000742	000662	27.0
	12	0000	004137	3341	.81	64.4	000628	000552	25.1
	13	0000	003784	3341	.88	75.7	000744	000645	25.6
	14	0000	004142	3226	.78	37.9	000375	000322	28.3
	15	0000	004139	2822	.68	98.4	001058	000936	25.6
	16	0000	003914	2592	.66	87.1	000911	000804	23.1
	17	0000	003815	2650	.69	68.1	000675	000595	21.1
	18	0000	003876	2650	.68	71.9	000730	000640	21.6
	19	0000	004027	2592	.64	41.6	000450	000395	22.0
	20	0000	003865	2592	.67	37.9	000419	000370	22.4
	21	0000	003772	2448	.65	56.7	000662	000588	22.6
	22	0000	004067	2016	.50	75.7	000890	000785	22.1
	23	0000	004415	2160	.49	75.7	000947	000872	23.6
	24	0000	004990	2160	.43	113.6	001376	001206	23.3
	25	0000	004005	2246	.56	102.2	001172	001027	19.4
	26	0000	004509	2189	.49	98.4	001099	000960	22.2
	27	0000	004614	2189	.47	102.2	001027	000891	20.5
	28	0000	004683	3024	.65	102.2	000912	000785	20.5
	29	0000	004401	3024	.69	75.7	000704	000614	30.3
	30	0000	004537	3276	.71	26.5	000283	000241	22.9
TOTAL		000000	123565	087784	21.71	2087.7	021501	018769	729.0
AVG		000000	004119	002926	.72	69.6	000717	000626	24.3
MAX		0000	004990	3802	1.14	113.6	001376	001206	30.3
MIN		0000	003336	2016	.43	22.7	000206	000174	19.4

04 69 FINAL EFFLUENT ANALYSES PROCESS A FORM C2

		TOT SUS SOLIDS			VOLATILE SUS SOLIDS			UNFILTERED BOD			FILTERED BOD				COLOR UNITS	So
DAY	DATE	PE	FE	P/CNT RED	PE	FE	P/CNT RED	PE	FE	P/CNT RED	PE	FE	P/CNT RED	PH	FE	FE
	01	064	036	43.8				630	104	83.5				7.4		
	02	132	068	48.5	100	040	60.0	620	098	84.2						
	03	240	108	55.0	160	064	60.0	545	086	84.2	424	056	86.8		285	
	04	136	108	20.6	128	084	34.4	525	106	79.8						
	05	152	054	64.5	148	048	67.6	572	070	87.8						
	06	116	018	84.5	112			538	094	90.0					290	
	07	112	052	53.6	104			417	082	80.3				7.4		
	08	136	040	70.6	136	038	72.1	380	050	86.8						
	09	120	030	75.0				435	056	87.1					215	
	10	112	032	71.4				570	038	93.3	198	050	87.4			
	11	124	032	74.2	120			540	048	91.1						
	12	120	035	72.7	116	030	74.1	482	041	91.5					282	
	13	080	025	68.8	072	013	81.9	487	045	90.8						
	14	152	042	72.4	108	027	75.0	507	054	89.3				7.6		
	15	160	037	76.9	128	026	79.7	435	064	85.3					305	
	16	140	027	80.7	108	016	85.2	420	046	89.0						
	17	100	017	83.0				485	032	93.5	413	013	96.9			
	18	140	028	80.0	096	017	82.3	400	026	93.5					277	
	19	140	026	81.4	104	026	75.0	567	032	94.4						
	20	112	045	59.8	080	037	53.8	493	032	93.5						
	21	176	042	76.1	132	030	77.3	530	063	88.1				7.4	280	
	22	124	034	72.6	112	028	75.0	535	064	88.0						
	23	168	056	66.7	120	041	65.8	560	058	89.5						
	24	088	080	9.1	040	072		385	038	90.1	205	014	95.1		240	
	25	104	020	84.8	144	024	83.3	470	040	91.5						
	26	112	015	86.6				459	032	93.0						
	27	120	026	78.3	092	021	77.2	408	034	91.7						
	28	172	056	68.6	152	052	65.8	400	058	85.8				7.5		
	29	116	022	81.0	104			495	044	91.1						
	30	168	050	70.2	128	040	68.8	505	040	92.1					240	
TOTAL		04024	01267		02044	00774		14793	1635		01520	0133		37.3	02632	
AVG		00134	00042	68.7	00114	00037	67.5	00493	0055	88.8	00380	0033	91.3	7.5	00270	.00
MAX		240	108	86.6	160	084	85.2	630	106	94.4	424	056	96.9	7.6	305	
MIN		064	015	9.1	040	013	34.4	380	026	79.8	205	013	86.8	7.4	215	

04 69 NUTRIENT DATA PROCESS A FORM D1

		NITROGEN						
		NH3 - N				NO3 - N		
DAY	DATE	PE	CS	PEF	RT	PEF	C-10	RT
	01							
	02							
	03	15.6		26.0	14.5			
	04						.4	
	05							
	06	17.0		29.1	6.4			2.4
	07							
	08						.9	
	09	15.0		23.1	16.5			1.4
	10							
	11						.5	
	12	9.7		17.2	10.7			1.3
	13							
	14						2.2	
	15	11.2		30.6	6.4			.8
	16							
	17						.7	
	18	10.2		21.3	9.0			.8
	19							
	20							
	21	13.6		27.8	14.2		2.6	1.6
	22							
	23						1.7	
	24	11.8		19.8	11.0			1.9
	25							
	26						1.6	
	27	13.3		25.4	22.3			.7
	28							
	29						.0	
	30	13.8		18.8	11.1			.6
TOTAL		130.1		229.1	116.4	.	10.5	11.6
AVG		13.0	00000	22.9	11.6	.0	1.2	1.3
MAX		17.0		29.1	22.3	.	2.6	2.4
MIN		9.7		17.2	6.4		.0	.6

04 69 NUTRIENT DATA PROCESS A FORM D2

		PHOSPHORUS									
		ORTHO			TOTAL			CELL TC CELLULAR		PEF BOD N.P. BOD = 100	
DAY	DATE	PE	CS	PEF	PI	PE	PEF	N	P	N	P
	01										
	02							8.8	1.8		
	03	1.1		4.7	3.4	3.9				4.8	.9
	04										
	05										
	06	.1		4.1	1.2	1.7				5.4	.8
	07										
	08										
	09	.9		5.0	4.1	6.5				5.9	1.1
	10										
	11							9.8	2.1		
	12	.9		4.4	4.3	4.1				5.6	.9
	13										
	14										
	15	.5		5.1	4.2	3.4				4.7	1.2
	16										
	17							9.5	2.2		
	18	.3		4.7	2.8	2.5				5.3	1.7
	19										
	20										
	21	.5		5.7	4.1	4.0				4.2	1.1
	22										
	23							10.3	2.1		
	24	.3		4.5	5.7	3.6				5.1	1.7
	25										
	26										
	27	.3		5.4	3.8	1.5				6.2	1.3
	28										
	29							7.8	1.5		
	30	1.4		5.0	4.6	4.6				3.7	.6
TOTAL		6.3		46.6	38.1	35.8	.	46.2	6.7	49.3	10.3
AVG		.6	0000	4.7	3.8	3.6	.0	9.2	1.9	4.9	1.0
MAX		1.4		5.7	5.7	6.5	.	10.3	2.2	6.2	1.7
MIN		.1		4.0	1.2	1.5		7.8	1.5	3.6	.6

06 69 AERATION TANK SOLIDS PROCESS B FORM F1

DAY	DATE	REAERATION SEC. TSS	VSS	P/CNT	CONTACT SEC. TSS	VSS	P/CNT	RETURN AND WASTE SLUDGE TSS	VSS	P/CNT
	01	07344	06000	83.0	4456	3764	84.5	07464	06344	85.0
	02	07532	06312	83.8	4592	3900	85.1	07720	06460	83.7
	03	07612	06712	88.2	5766	4686	81.4	08132	06876	84.6
	04	08656	07356	85.0	4928	4188	85.0	09776	08284	84.7
	05	09512	08076	84.9	5170	4382	84.9	09536	08116	85.1
	06	09236	07810	84.6	4860	4154	85.5	09772	08372	85.7
	07	08936	07544	84.4	4562	3936	86.1	10004	08676	86.7
	08	10324	08692	84.2	4796	3860	80.5	11004	09320	84.8
	09	11376	09700	85.3	4680	3696	84.0	11104	09492	85.4
	10	11096	09812	81.3	4412	3820	86.6	10556	09000	85.3
	11	11096	09496	85.6	4244	3748	88.4	11088	09692	87.4
	12	10612	09160	86.4	4304	3760	87.5	10736	09420	87.7
	13	10312	08896	86.3	4414	3842	87.0	10604	09226	87.2
	14	10012	08624	86.1	4524	3912	86.5	10432	09032	86.6
	15	10760	09324	86.6	4056	3552	87.6	10464	08706	88.4
	16	10596	09244	87.2	4426	3912	88.5	10796	09432	87.4
	17	10848	09328	86.0	4184	3746	89.3	11044	09460	85.7
	18	10972	09500	86.7	4412	3892	88.2	11528	09996	86.7
	19	11700	10116	86.4	4142	3580	86.3	09428	08112	88.7
	20	11364	09826	86.6	4070	3596	87.4	09518	08366	87.7
	21	10400	08956	86.8	3968	3532	88.6	09648	08420	87.3
	22	09856	08520	81.4	3600	3172	87.1	10448	08968	85.6
	23	09960	08584	86.2	3868	3332	86.1	10692	09224	86.3
	24	10984	09420	85.8	3668	3184	86.0	11504	09920	86.3
	25	11364	09772	86.0	4188	3586	85.6	11676	10100	86.6
	26	11590	09972	86.0	4706	3980	83.4	08720	07480	85.0
	27	11414	09742	85.4	4124	3526	85.5	09926	08504	85.7
	28	11232	09512	84.7	3968	3466	87.3	11132	09528	85.6
	29	10816	08870	81.2	4452	3876	87.1	10788	09280	86.0
	30	11004	09412	85.5	3870	3340	86.2	11076	09532	86.1
TOTAL		308996	264322		130946	112480		306062	264512	
AVG		010300	008811	85.5	004365	003749	86.0	010220	008817	86.2
MAX		11700	10116	88.2	5766	4686	89.6	11676	10100	88.4
MIN		07344	06000	81.3	3600	3172	80.5	07464	06344	83.7

06 69 SUPPLEMENTAL OPERATING DATA PROCESS B FORM F1

DAY	DATE	FEED BYPASS L/D	G ACT L/D	RAS ACT L/D	R/Q RATIO	WAS ACT L/D	SOL. WASTED GRAMS / DAY TSS	VSS	F.C. TSS LOAD LB/SF/D
	01	0000	003356	4404	1.34	50.3	000276	000192	24.4
	02	0000	003403	4032	1.18	53.0	000410	000363	23.9
	03	0000	003432	3744	1.09	60.6	000493	000417	24.6
	04	0000	003683	3110	.84	60.6	000592	000502	23.5
	05	0000	003664	2862	.78	100.6	001047	000891	27.1
	06	0000	003569	2592	.72	98.4	000961	000824	21.1
	07	0000	004235	2765	.65	50.3	000303	000261	22.5
	08	0000	004752	2536	.53	96.0	000625	000530	24.5
	09	0000	004664	2536	.54	106.0	001177	001006	22.7
	10	0000	004301	2336	.50	96.0	000990	000852	21.3
	11	0000	004362	2304	.53	113.6	001260	001101	19.8
	12	0000	004137	2206	.54	113.6	001220	001070	19.3
	13	0000	003970	2246	.56	113.6	001202	001048	16.7
	14	0000	004162	2016	.48	66.4	000672	000582	19.5
	15	0000	004159	2131	.51	45.4	000499	000441	17.8
	16	0000	003914	2016	.52	66.4	000695	000607	18.4
	17	0000	003815	2016	.53	98.4	001067	000933	17.4
	18	0000	003876	1872	.48	98.4	001134	000984	17.2
	19	0000	004027	1728	.43	109.8	001035	000911	16.8
	20	0000	003865	1728	.45	102.2	000975	000855	16.0
	21	0000	003772	1728	.46	113.6	001096	000957	15.4
	22	0000	004087	2016	.50	68.1	000712	000609	15.5
	23	0000	004919	2016	.41	41.6	000445	000384	18.0
	24	0000	004990	2160	.43	54.1	000392	000339	18.4
	25	0000	004005	2074	.52	66.4	000752	000651	17.9
	26	0000	004509	2074	.46	96.8	000495	000425	19.9
	27	0000	004614	2074	.45	60.6	000602	000515	19.3
	28	0000	004681	2218	.47	60.6	000675	000577	19.1
	29	0000	004401	2218	.50	75.7	000817	000702	20.7
	30	0000	004517	2304	.51	71.9	000796	000685	18.6
TOTAL		000000	123565	072086	17.90	2271.6	023394	020194	600.1
AVG		000000	004119	002403	.60	75.7	000780	000673	20.0
MAX		0000	004990	4404	1.34	113.6	001260	001101	29.0
MIN		0000	003356	1728	.41	50.3	000276	000192	15.4

06 69 NUTRIENT DATA PROCESS B FORM G1

N I T R O G E N

DAY	DATE	NH3 - N PE	DS	PEF	RT	NO3 - N PEF	C-10	RT
	01							
	02							
	03	15.0		30.0	22.0			
	04						.8	
	05							
	06	17.0		30.0	11.0			1.1
	07							
	08						1.8	
	09	15.0		22.6	10.5			2.2
	10							
	11						.5	
	12	9.2		17.0	10.2			.7
	13							
	14						1.7	
	15	11.2		20.3	5.3			1.2
	16							
	17						.6	
	18	10.2		21.0	10.0			.9
	19							
	20							
	21	13.6		26.6	12.7		1.0	2.1
	22							
	23						5.7	
	24	11.0		20.1	4.1			1.4
	25							
	26						1.6	
	27	15.3		24.0	13.1			1.9
	28							
	29						1.9	
	30	13.0		19.3	2.5			.6
TOTAL		130.1		231.7	102.5	.	12.1	11.9
AVG		13.0	00000	23.2	10.3	.0	1.3	1.3
MAX		17.0		30.0	22.0	.	5.7	2.2
MIN		9.2		17.0	2.5		.5	.6

06 69 AERATION TANK SOLIDS PROCESS B FORM E2

DAY	DATE	DIGESTER SUPERNATANT TSS	VSS	NIR	L/D ADDED	GRAMS TSS ADDED	DS-TSS PE TSS	S P T S L V O L U M E 10 MIN	30 MIN	30 MIN SVI	CLAR. SLUDGE LEVEL	F/M RATIO TC VSS	BOD VSS
	01							0990	0950	00213	62	.30	.33
	02							0990	0960	00209	61	.28	.32
	03							0985	0970	00169	61	.26	.28
	04							0990	0870	00177	53	.26	.26
	05							0990	0960	00187	53	.25	.26
	06										53	.24	.26
	07							0990	0960	00200	53	.26	.26
	08							0990	0980	00204	52	.26	.23
	09							0990	0970	00220	52	.26	.28
	10							0990	0960	00218	52	.26	.32
	11							0990	0960	00222	52	.26	.26
	12							0980	0960	00223	52	.26	.25
	13										44	.25	.24
	14							0990	0960	00212	65	.26	.27
	15							0990	0960	00237	52	.24	.23
	16							0980	0960	00213	53	.23	.20
	17							0980	0950	00211	52	.22	.24
	18							0990	0960	00210	27	.23	.19
	19							0990	0960	00226	19	.25	.28
	20										00	.22	.24
	21							0970	0960	00236	00	.26	.23
	22							0980	0890	00245	00	.31	.31
	23							0970	0650	00168	00	.33	.37
	24							0990	0860	00234	00	.30	.26
	25							0980	0960	00224	00	.25	.23
	26							0980	0990	00221	00	.24	.25
	27										14	.26	.24
	28							0990	0930	00236	28	.27	.24
	29							0990	0960	00216	52	.27	.28
	30							0990	0930	00240	52	.27	.26
TOTAL					.		.	25570	24240	05594	1094	7.73	7.00
AVG		000000	000000	00000	.0	000000	.0	00983	00932	00215	0036	.26	.28
MAX					.		.	0990	0980	00245	62	.33	.37
MIN								0970	0650	00168	00	.22	.19

06 69 FINAL EFFLUENT ANALYSES PROCESS B FORM F2

DAY	DATE	TOT SUS SOLIDS PE	FE	P/CNT REC	VOLATILE SUS SOLIDS PE	FE	P/CNT RED	UNFILTERED BOD PE	FE	P/CNT RED	FILTERED BOD PE	FE	P/CNT RET	PH	COLOR UNITS FE	S? PE
	01	064	018	71.9				630	052	91.7						
	02	132	036	72.7	100	028	72.0	620	038	93.9				7.6		
	03	240	052	78.3	166	034	79.6	545	040	92.7	424	036	91.5		277	
	04	136	056	58.8	120	040	66.1	525	066	88.6						
	05	152	024	84.2	144			572	033	94.2						
	06	116	042	63.8	12	030	66.1	530	025	95.4					300	
	07	112	026	76.8	104			417	056	87.1				7.5		
	08	136	036	73.5	136	034	75.0	380	046	87.9						
	09	120	018	85.0				455	040	90.8					325	
	10	112	004	96.4				570	030	94.7	390	020	95.0			
	11	124	027	82.3	120			540	062	88.5						
	12	120	021	83.6	116	018	84.5	402	032	93.4					315	
	13	080	026	67.5	072	016	77.8	487	050	89.7						
	14	152	038	75.0	100	026	74.1	507	068	86.6				7.7		
	15	160	016	90.0	128	036	70.7	435	064	85.3					310	
	16	140	031	77.9	108	027	75.0	420	056	86.7						
	17	100	014	86.0				485	038	92.3	413	017	95.9			
	18	140	020	85.7	096	018	81.3	466	030	92.5					290	
	19	140	026	81.4	104	022	78.8	567	032	94.4						
	20	112	031	72.3	086	029	68.0	493	053	89.2						
	21	176	043	75.6	112	024	78.6	530	058	89.1				7.6	246	
	22	124	037	70.2	112	035	68.8	515	080	85.0						
	23	168	062	63.1	120	060	50.0	546	096	82.2						
	24	088	064	27.3	080	080		305	070	79.7	205	020	90.2		255	
	25	104	080	56.5	104	046	56.2	470	112	76.2						
	26	112	044	60.7				450	093	79.3						
	27	120	083	30.8	092	064	30.4	400	077	81.1						
	28	172	090	47.7	152	074	51.3	408	069	83.1				7.6		
	29	116	020	[illegible]	104			495	050	89.9						
	30	160	034	78.8	120	028	78.1	505	034	93.3					252	
TOTAL		04024	01122		02044	00700		14793	1856		01520	0109		38.0	02510	
AVG		00134	00037	72.4	00114	00036	68.4	00493	0055	88.8	00380	0027	92.9	7.6	00279	.00
MAX		260	090	96.4	166	074	85.0	630	112	95.4	424	036	95.9	7.7	315	
MIN		064	004	27.3	072	016	30.4	305	025	76.2	205	017	90.2	7.5	246	

06 69 NUTRIENT DATA PROCESS B FORM G2

P H O S P H O R U S

	DATE	O R T H O PE	DS	PEF	T O T A L PE	PE	PEF	CELL 10 CELLULAR N	P	PEF BOD N.P. BOD = 100 N	P
	01										
	02							9.7	2.5		
	03	1.1		6.1	3.0	3.9				5.5	1.1
	04										
	05										
	06	.3		4.3	1.2	1.1				5.6	.8
	07										
	08										
	09	.9		9.7	9.1	8.5				5.2	1.1
	10										
	11							9.6	2.1		
	12	.8		4.3	4.7	6.1				5.5	.8
	13										
	14										
	15	.5		5.0	4.7	3.4				4.7	1.1
	16										
	17							9.5	2.2		
	18	.3		4.6	2.8	2.3				5.3	1.2
	19										
	20										
	21	.5		5.3	4.1	4.0				5.0	1.0
	22										
	23							9.2	2.0		
	24	.3		4.2	5.7	3.6				5.2	1.2
	25										
	26										
	27	.3		5.2	3.0	1.5				5.1	1.3
	28										
	29							10.2	1.5		
	30	1.4		3.2	4.6	4.6				5.4	.6
TOTAL		6.3		47.5	38.1	35.8	.	48.7	10.5	49.8	16.3
AVG		.6	0000	4.7	3.8	3.6	.0	9.6	2.1	5.0	1.0
MAX		1.4		6.1	5.7	6.5	.	10.2	2.5	5.5	1.3
MIN		.3		3.2	1.2	1.5		9.2	1.5	4.5	.6

06 69 AERATION TANK SOLIDS PROCESS C FORM H1

DAY	DATE	AERATION SEC. TSS	VSS	P/CNT	CONTACT SEC. TSS	VSS	P/CNT	RETURN AND WASTE SLUDGE TSS	VSS	P/CNT
	01	14464	11604	79.6	5956	4808	80.7	15880	12604	79.4
	02	15032	11896	79.1	5900	4800	81.0	16440	13300	80.9
	03	16320	12944	79.4	5904	4828	81.8	17402	14278	81.9
	04	16996	13552	80.0	5296	4640	81.4	18364	14912	81.2
	05	16428	13320	81.1	5124	4104	80.0	14628	12536	81.3
	06	15074	12180	80.0	5604	4500	80.0	16276	13200	81.5
	07	13720	11032	80.4	5604	4620	80.7	17124	14000	81.8
	08	16532	13032	81.3	4504	3716	82.5	17204	13920	80.7
	09	16200	13056	80.1	4832	4004	82.9	16672	13720	82.3
	10	13036	12069	77.2	4965	4020	81.5	12828	10568	82.4
	11	16044	13008	81.1	5052	4120	81.6	20624	17296	83.9
	12	16900	13800	82.2	5080	4200	82.8	17196	14200	83.1
	13	16900	13800	81.4	5000	4070	82.7	16524	13772	83.0
	14	14780	12064	81.6	6710	5548	82.6	15888	13176	83.0
	15	16268	13220	82.3	5252	4412	84.0	14660	12280	83.8
	16	13920	11512	82.7	5032	4720	83.5	14996	12564	83.8
	17	14644	12048	82.3	5520	4588	83.1	15804	13096	82.9
	18	15408	12620	82.2	5960	4980	82.3	17476	14520	83.1
	19	17252	14096	81.7	5072	4360	85.6	15964	13624	84.2
	20	16787	13850	82.5	5346	4558	85.4	17330	14610	84.4
	21	16512	13604	83.4	5600	4776	85.2	18716	15836	84.6
	22	15552	13070	84.5	6052	5032	83.5	19412	16484	84.9
	23	19180	16276	83.9	5000	4240	84.8	23060	19604	85.0
	24	21504	18124	84.3	6100	5452	84.4	20500	17464	85.2
	25	17290	14596	84.7	6304	5420	84.9	23024	20228	84.9
	26	17396	14744	84.8	6016	5304	82.3	17596	14896	84.7
	27	14916	12567	83.8	4612	3850	83.5	16724	14040	84.0
	28	12424	10280	82.6	5200	4396	84.5	15852	13104	83.2
	29	14020	11416	81.4	5236	4218	80.5	16576	13744	83.9
	30	16264	13420	82.5	4512	3720	82.4	18496	15192	82.1
TOTAL		482956	395766		158228	130996		521046	433500	
AVG.		016099	013192	81.9	005274	004367	82.8	017368	014443	83.2
MAX		21504	18124	84.8	6716	5548	85.6	23024	20228	85.2
MIN		12424	10260	77.2	4016	3584	80.5	12828	10568	79.4

06 69 AERATION TANK SOLIDS PROCESS C FORM H2

DIGESTER SUPERNATANT

DAY	DATE	TSS	VSS	BOD	L/D ADDED	GRAMS TSS ADDED	DS-TSS PC TSS	SETTL. VOLUME 10 MIN	30 MIN	30 MIN SVI	CLAR. SLUDGE LEVEL	F/M RATIO TC VSS	BOD VSS
	01	11652			90.7	001057	4.9	0910	0900	00151	41	.26	.29
	02	11652			96.5	001124	2.5	0900	0800	00138	42	.26	.30
	03	15356	9032	2370	95.0	001459	1.8	0960	0840	00142	41	.23	.26
	04	15356			82.1	001261	2.5	0960	0860	00151	41	.23	.25
	05	15356			86.4	001327	2.4	0960	0830	00107	41	.30	.27
	06	15356			90.7	001393	3.3				41	.26	.27
	07	16820	8640	2260	96.5	001623	1.6	0960	0870	00158	41	.29	.26
	08	16820			96.5	001623	2.5	0900	0900	00111	00	.29	.20
	09	10724	5800	2070	95.0	001019	1.8	0920	0780	00161	00	.27	.28
	10	10724			83.5	000895	1.6	0960	0750	00152	00	.29	.30
	11	10724			87.8	000942	1.7	0960	0800	00158	00	.28	.32
	12	11660	6840	2141	95.0	001108	2.1	1050	0500	00098	00	.26	.25
	13	11660			95.0	001108	1.7				14	.25	.23
	14	11660			85.0	000992	1.6	0990	0950	00141	15	.26	.27
	15	12696	6468	2175	90.7	001152	1.7	0970	0910	00175	00	.26	.24
	16	12696			56.2	000714	1.1	0960	0800	00154	00	.26	.23
	17	12696			57.6	000731	1.9	0960	0900	00167	00	.25	.26
	18	08572	5296	1965	57.6	000494	.9	0980	0810	00163	00	.26	.21
	19	08572			63.4	000543	1.0	0980	0880	00174	00	.28	.28
	20	08572			63.4	000543	1.3				00	.23	.24
	21	09544	5284	2134	61.9	000591	.9	0980	0940	00158	00	.26	.25
	22	09544			60.5	000577	1.1	0960	0900	00185	00	.27	.27
	23	09544			61.9	000591	.7	0990	0880	00176	00	.29	.32
	24	06148	4516	1770	54.7	000336	.8	0816	0500	00127	10	.26	.23
	25	06148			63.4	000390	.9	0980	0970	00151	40	.31	.22
	26	06148			46.1	000283	.6	0900	0960	00209	33	.27	.28
	27	08088	6004	2283	61.9	000501	.9				28	.30	.27
	28	08088			79.2	000641	.8	0980	0960	00180	26	.32	.29
	29	08088			49.0	000396	.8	0980	0980	00181	24	.31	.32
	30	07360	5200	2170	47.5	000351	.5	0980	0880	00180	26	.29	.32
TOTAL		320076	062096	21839	2290.7	025765	51.7	24780	21460	04082	0511	7.96	8.09
AVG.		010936	006246	02184	76.0	000859	1.7	00951	00825	00157	0017	.27	.27
MAX		16820	8640	2370	96.5	001623	4.9	0990	0970	00209	49	.32	.36
MIN		06148	4516	1770	46.1	000283	.5	0810	0500	00098	00	.21	.21

06 69 SUPPLEMENTAL OPERATING DATA PROCESS C FORM J1

DAY	DATE	FEED BYPASS L/C	% ACT L/D	RAS ACT L/D	R/Q RATIO	WAS ACT L/D	SOL. WASTED GRAMS / DAY TSS	VSS	F.C. TSS LOAD LB/SF/D
	01	0000	003936	1400	.45	90.0	001442	001192	20.2
	02	0000	003403	1595	.46	90.0	000956	000795	19.1
	03	0000	003432	1302	.40	106.0	001907	001561	19.9
	04	0000	003683	1210	.33	60.6	001113	000906	19.6
	05	0000	003564	1494	.42	121.1	001868	001518	18.9
	06	0000	003509	1490	.42	113.8	001869	001507	19.3
	07	0000	004235	1526	.36	56.0	000971	000795	22.2
	08	0000	004752	1843	.39	71.9	001240	001001	20.8
	09	0000	004604	1843	.40	74.7	001262	001040	23.1
	10	0000	004301	1843	.42	54.0	000720	000600	21.5
	11	0000	004462	1843	.42	37.9	000782	000656	21.9
	12	0000	004137	1901	.46	90.4	001651	001404	21.5
	13	0000	003784	1901	.50	102.2	001679	001402	23.5
	14	0000	004142	1720	.42	124.9	001982	001646	27.7
	15	0000	004139	1786	.43	113.6	001604	001348	21.8
	16	0000	003916	1728	.44	90.6	001465	001109	22.9
	17	0000	003815	1728	.45	60.6	000958	000796	21.5
	18	0000	003876	1613	.42	60.6	001059	000880	21.6
	19	0000	004027	1411	.35	60.6	000966	000813	19.3
	20	0000	003805	1411	.37	50.0	000904	000831	19.8
	21	0000	003772	1296	.34	60.6	001134	000960	19.9
	22	0000	004067	1296	.32	79.5	001543	001310	18.3
	23	0000	004919	1152	.23	22.7	000523	000445	21.3
	24	0000	004998	1728	.35	71.9	001474	001296	19.3
	25	0000	006005	1782	.35	94.6	002254	001914	24.1
	26	0000	004504	1296	.29	109.3	003331	002820	16.4
	27	0000	004514	1296	.28	212.0	003545	002976	19.1
	28	0000	004603	1584	.34	65.3	001320	001090	22.4
	29	0000	004401	1728	.39	75.7	001240	001040	22.5
	30	0000	004532	2016	.44	68.1	001260	001035	20.7
TOTAL		00000	123565	047520	11.64	2570.0	044121	036696	628.9
AVG.		00000	004119	001584	.38	85.6	001471	001223	21.0
MAX		0000	006005	2016	.50	212.0	003545	002976	27.7
MIN		0000	003336	1152	.23	22.7	000523	000445	16.4

06 69 FINAL EFFLUENT ANALYSES PROCESS C FORM J2

DAY	DATE	TOT SUS SOLIDS PE	FE	P/CNT RED	VOLATILE SUS SOLIDS PE	FE	P/CNT RED	UNFILTERED BOD PE	FE	P/CNT RED	FILTERED BOD PE	FE	P/CNT RED	PH	COLOR UNITS FE	S= FE
	01	064	034	46.9				630	098	85.7				7.6		
	02	132	040	69.7	100	024	76.0	620	074	88.1						
	03	240	072	70.0	160	018	76.3	565	062	88.6	424	041	90.3		312	
	04	136	066	51.5	128	036	56.3	525	098	81.3						
	05	152	040	73.7	144			532	076	87.8						
	06	116	032	72.4	112			530	036	93.3					310	
	07	112	030	73.2	104			417	078	81.3				7.6		
	08	136	040	70.6	136			300	058	86.7						
	09	120	036	71.7		058		435	040	90.8					320	
	10	112	022	80.4				510	038	91.3	288	032	92.0			
	11	124	034	72.6	120			540	050	90.7						
	12	120	026	79.7	116	023	80.2	482	048	90.0					310	
	13	080	025	68.8	072	022	69.4	487	048	90.1						
	14	152	039	74.3	108	028	74.1	507	060	88.2				7.2		
	15	160	023	85.6	128	022	82.8	435	042	90.3					323	
	16	140	026	81.4	108	019	82.4	420	038	91.0						
	17	100	019	81.0				495	032	93.5	411	014	96.6			
	18	140	038	72.9	096	027	71.9	400	032	92.0					294	
	19	140	037	73.6	104	030	71.2	567	041	92.8						
	20	112	044	60.7	080	029	63.8	493	032	93.5						
	21	176	056	68.2	132	044	66.7	530	060	88.7				7.6	335	
	22	124	094	24.2	112	084	25.0	535	108	79.8						
	23	168	092	45.2	120	068	43.3	540	132	75.6						
	24	088	244		040			385	120	68.8	205	066	67.8		261	
	25	184	102	44.6	144	080	44.4	470	152	67.7						
	26	112	142			110		459	138	69.9						
	27	120	137		092	110		408	113	72.3						
	28	172	094	45.3	152	076	50.0	408	089	78.2				7.0		
	29	116	042	63.8	104			485	090	81.4						
	30	168	056	66.7	120	038	70.3	509	096	81.1					292	
TOTAL		04024	01775		02844	00950		14793	2123		01420	0183		37.5	02679	
AVG.		00134	00059	56.0	00114	00048	57.9	00493	00071	85.6	[illegible]	[illegible]	91.3	7.5	00297	.00
MAX		240	244	85.6	160	110	82.8	630	152	93.5	424	066	96.6	7.7	335	
MIN		064	019	24.2	040	018	25.0	300	032	67.7	205	014	67.8	7.0	261	

06 69 NUTRIENT DATA PROCESS C FORM K1

N I T R O G E N

DAY	DATE	NH3 - N PE	ES	RED		ST	NO3 - N PEF	C-10	RT
	01								
	02								
	03	14.7	720	34.6		99.0			
	04							.9	
	05								
	06	17.0	480	33.6		74.5			1.3
	07								
	08							.4	
	09	16.0	700	29.2		61.0			2.4
	10								
	11							1.3	
	12	9.2	675	24.2		101.0			.9
	13								
	14							2.2	
	15	11.2	575	25.7		26.0			.9
	16								
	17							1.1	
	18	10.2	710	20.8		69.2			1.6
	19								
	20								
	21	13.6	696	26.8		38.1		2.3	1.7
	22								
	23							.4	
	24	11.8	603	18.4	1.8	25.0			.9
	25								
	26							1.9	
	27	15.3	677	22.4		6.3			1.1
	28								
	29							.6	
	30	13.0	499	18.9		93.3			.9
TOTAL		130.1	06509	251.6		517.4	.	10.9	11.5
AVG.		13.0	00651	25.2		51.7	.0	1.2	1.3
MAX		17.0	720	34.9		101.0	.	2.3	2.4
MIN		9.2	499	18.4		6.3		.4	.9

06 69 NUTRIENT DATA PROCESS C FORM K2

P H O S P H O R U S

DAY	DATE	ORTHO PE	ES	PEF		TOTAL PE	PS	PEF		CELL SC CYCLOSIS N	P	PER BOD R.P. BOD = 100 N	P
	01												
	02									6.6	2.7		
	03	1.1	227	1.9		3.9	3.9					6.5	1.9
	04												
	05												
	06	.1	141	6.7		1.3	1.7					6.2	1.6
	07												
	08												
	09	.9	323	2.1		4.1	4.1					4.7	1.7
	10												
	11									6.7	2.8		
	12	.4	104	5.1		4.2	4.1					5.1	1.1
	13												
	14												
	15	.8	127	3.3		4.2	3.9					5.4	.8
	16												
	17									6.0	2.0		
	18	.3	114	2.0		3.8	2.9					5.2	.3
	19												
	20												
	21	.5	131	2.6		4.1	4.0					4.7	.5
	22												
	23									6.4	1.5		
	24	.3	079	1.2		5.7	3.6					4.0	.3
	25												
	26												
	27	.3	092	1.5		3.8	1.5					5.5	.4
	28												
	29									6.2	1.4		
	30	1.4	061	2.0	.	4.6	4.6					3.7	.4
TOTAL		6.3	1679	41.3	2	48.1	35.8	.		41.7	9.2	53.7	6.7
AVG.		.6	0168	4.1	.3	3.8	3.6	.0	73.7	6.7	1.8	5.4	.9
MAX		1.4	323	6.7	.7	5.7	4.6	.	90.5	9.2	2.2	6.7	1.9
MIN		.1	061	1.2	.1	1.2	1.5		6.3	6.4	1.4	3.7	.3

04 69 AERATION TANK SOLIDS PROCESS D FORM 11

DAY DATE	REAERATION SEC. TSS	VSS	PRCNT	CONTACT SEC. TSS	VSS	PRCNT	RETURN AND WASTE SLUDGE TSS	VSS	PRCNT
01	12992	10196	78.5	6960	5632	79.9	13868	11076	79.9
02	12720	09956	78.5	4008	3071	80.5	13976	11100	79.9
03	13816	10900	78.9	4744	3892	82.0	14084	11204	80.1
04	13620	10988	80.6	6080	3700	80.7	15012	12504	81.1
05	14108	11200	79.5	4520	3632	80.2	13992	10000	80.3
06	13152	10670	79.7	4656	3720	80.1	14340	11628	81.0
07	12116	09676	79.9	4780	3820	79.9	15104	12548	81.0
08	14632	11520	80.7	4490	3760	83.7	15504	12600	81.8
09	14696	11732	80.9	4168	3172	76.1	13880	11200	81.7
10	12592	10792	85.7	4484	3628	80.9	17004	13976	81.0
11	13352	10908	81.7	4272	3568	82.6	12928	10512	84.1
12	12900	10688	83.3	4656	3908	85.2	13604	11312	83.2
13	12204	10072	82.5	4560	3952	86.2	14220	11856	83.2
14	11616	09670	81.6	4516	3936	87.2	14896	12364	83.3
15	14070	11694	83.3	4268	3668	85.9	13992	11688	83.5
16	13096	10792	82.8	4576	3880	84.4	16172	11812	83.3
17	14156	11720	82.8	4600	3916	81.0	13924	11596	83.0
18	13624	11232	82.4	4200	3560	84.3	14248	11880	83.4
19	13620	11164	82.7	3848	3048	80.5	13264	11180	84.3
20	13620	11122	82.9	4400	3512	82.0	14004	11000	84.1
21	13620	11160	85.0	4148	3528	85.1	14744	12412	84.2
22	14108	11780	83.5	4044	3324	82.1	15326	12932	84.4
23	14560	11488	82.4	4256	3640	85.9	20460	17000	83.9
24	15504	12960	83.6	1936	1616	80.6	17312	14600	84.6
25	13996	11276	82.9	4600	3960	83.0	15204	12952	85.2
26	13000	10764	82.8	4120	3392	82.3	13920	11760	84.5
27	12224	10144	83.0	4028	3326	82.6	11840	10060	84.9
28	11440	09526	83.2	3936	3260	82.8	09704	08352	85.5
29	09616	07888	73.1	3672	3026	82.5	08256	07028	85.1
30	08660	07260	83.6	3160	2651	83.9	06456	05272	81.7
TOTAL	391520	320950		126100	104302		418036	347066	
AV.	013051	010698	82.0	004203	003477	82.7	013934	011568	82.9
MAX	15504	12960	85.7	4800	3960	88.0	20360	17000	85.5
MIN	08632	07260	78.5	1936	1616	76.1	06456	05272	79.9

04 69 SUPPLEMENTAL OPERATING DATA PROCESS D FORM M1

DAY DATE	EFFL BYPASS L/D	Q ACT L/D	RAS ACT L/D	R/Q RATIO	WAS ACT L/D	SLG. WASTED GRAMS / DAY TSS	VSS	F.C. TSS LOAD LB/SF/D
01	0000	013336	1526	.46	38.9	000925	000620	19.5
02	0000	013401	1511	.41	55.0	000761	000592	16.2
03	0000	013412	1354	.39	90.0	001279	001025	19.9
04	0000	013683	1325	.36	94.4	001517	001230	16.9
05	0000	013864	1296	.36	102.2	001389	001115	15.4
06	0000	013569	1296	.38	106.0	001521	001233	15.9
07	0000	014235	1296	.31	41.6	000620	000514	16.5
08	0000	014752	1296	.27	90.4	001526	001248	19.1
09	0000	014664	1584	.34	71.9	000999	000811	18.3
10	0000	014961	1584	.36	75.7	001293	001058	18.7
11	0000	014942	1584	.36	75.7	000960	000787	17.8
12	0000	014137	1440	.35	117.3	001596	001327	18.2
13	0000	013784	1440	.38	121.1	001772	001434	16.8
14	0000	014142	1267	.31	37.9	000562	000469	17.1
15	0000	014159	1325	.32	102.2	001630	001195	16.4
16	0000	023914	1152	.29	94.6	001391	001117	16.3
17	0000	013815	1325	.35	30.3	000616	000565	15.0
18	0000	013876	1325	.34	71.9	001024	000854	15.3
19	0000	014127	1267	.31	11.4	000151	000128	14.9
20	0000	013865	1267	.33	56.8	000795	000670	14.9
21	0000	013772	1267	.34	64.4	000950	000790	14.7
22	0000	014067	1296	.32	60.6	000920	000786	15.2
23	0000	014914	1152	.23	30.3	000617	000515	18.0
24	0000	014399	1324	.35	60.6	001049	000885	9.7
25	0000	014005	1440	.38	71.9	001093	000931	17.0
26	0000	014505	1555	.38	75.7	001096	000901	17.5
27	0000	014614	1555	.38	79.5	000942	000800	17.4
28	0000	014661	1872	.40	206.3	002014	001723	18.1
29	0000	014401	2448	.56	17.9	000315	000266	17.6
30	0000	014512	4320	.95	30.3	000196	000160	19.6
TOTAL	000000	425965	045983	11.15	2212.6	030990	025336	491.9
AV.	000.00	014119	001533	.37	73.8	001019	000845	16.4
MAX	0000	014940	4320	.95	206.3	002014	001723	19.6
MIN	0000	013336	1152	.23	11.4	000151	000128	9.7

04 69 NUTRIENT DATA PROCESS D FORM N1

N I T R O G E N

DAY DATE	NH3 - N PE	CS	PRD	ET	NO3 - N DEF	C-10	ET
01							
02							
03	15.6	720	31.6	65.0			
04						.9	
05							
06	17.0	880	31.6	64.3			2.0
07							
08						.7	
09	15.0	100	26.7	45.0			3.3
10							
11						.3	
12	9.2	619	20.0	52.0			.9
13							
14						.8	
15	11.2	836	20.7	42.0			1.6
16							
17						.8	
18	10.2	730	20.8	44.2			1.3
19							
20							
21	15.6	686	36.0	36.0		1.1	1.8
22							
23						.8	
24	11.0	603	18.4	44.9			.8
25							
26						.9	
27	15.5	677	31.5	75.0			.8
28							
29						.8	
30	19.0	480	22.0	22.9			1.0
TOTAL	130.1	06505	232.8	411.9		6.4	16.5
AV.	15.0	00651	23.8	41.4	.8	.8	1.6
MAX	17.0	880	31.8	65.0		1.1	2.2
MIN	9.2	480	18.4	22.9		.8	.8

04 69 AERATION TANK SOLIDS PROCESS D FORM 12

DAY DATE	DIGESTER SUPERNATANT TSS	VSS	BOD	L/D ADDED	GRAMS TSS ADDED	DS-TSS PC TSS	SETTLED VOLUME 10 MIN	30 MIN	30 MIN SVI	CLAR. SLUDGE LEVEL	F/M RATIO TC VSS	BOD VSS
01	11652			79.2	000928	4.1	0980	0920	00202	41	.20	.22
02	11652			79.2	000923	2.1	0970	0920	00191	41	.19	.22
03	15356	7932	2190	79.2	001216	1.5	0970	0920	00196	41	.17	.18
04	15356			77.8	001195	2.4	0980	0920	00197	41	.17	.19
05	15356			79.2	001216	2.2	0980	0900	00188	41	.18	.20
06	15356			79.2	001216	2.9				41	.19	.20
07	16820	8640	2260	79.2	001332	2.0	0980	0960	00188	41	.23	.18
08	16820			79.2	001332	2.1	0980	0920	00205	00	.19	.18
09	10724	5000	2070	77.8	000836	1.5	0970	0900	00214	00	.20	.21
10	10724			67.7	000726	1.5	0980	0880	00196	00	.20	.25
11	10724			69.1	000741	1.4	0970	0880	00206	00	.22	.24
12	11668	6648	2141	66.2	000772	1.5	0960	0900	00193	00	.21	.20
13	11668			66.2	000772	2.6				00	.20	.16
14	11668			72.0	000840	1.3	0980	0950	00210	00	.21	.22
15	12696	6060	2175	69.1	000877	1.3	0980	0940	00220	00	.16	.17
16	12696			57.6	000731	1.3	0970	0920	00201	00	.18	.16
17	12696			57.6	000731	1.9	0980	0810	00251	00	.15	.25
18	08572	5256	1965	57.6	000494	.9	0990	0900	00224	00	.19	.16
19	08572			54.7	000469	.8	0870	0950	00267	00	.22	.24
20	08572			54.7	000469	1.1				00	.18	.20
21	09544	5284	2194	56.1	000535	.8	0980	0960	00231	[illegible]	.20	.20
22	09544			57.6	000550	1.1	0980	0960	00237	00	.22	.22
23	09544			53.3	000509	.6	0990	0940	00232	50	.25	[illegible]
24	06144	4516	1770	54.7	000336	.6	0980	0760	00142	45	.26	[illegible]
25	06144			57.6	000354	.5	0980	0980	00213	41	.18	.18
26	06144			56.2	000346	.7	0990	0980	00230	54	.21	.22
27	08088	6004	2203	56.2	000455	.8				59	.22	.21
28	08088			56.2	000455	.6	0980	0980	00249	59	.24	.22
29	08088			44.6	000361	.7	0980	0970	00266	66	.27	.28
30	07388	5208	2170	82.1	000607	.8	0995	0970	00307	70	.30	.33
TOTAL	328076	062656	21330	1977.1	022317	46.0	24815	23630	05659	0729	6.21	6.56
AVG	010936	006266	02134	65.9	000744	1.5	00994	[illegible]	00218	0026	.21	.21
MAX	16820	8640	2370	82.1	001332	4.1	0995	0980	00307	70	.30	.33
MIN	06144	4516	1770	44.6	000336	.5	[illegible]	0760	00142	00	.17	.16

04 69 FINAL EFFLUENT ANALYSES PROCESS D FORM M2

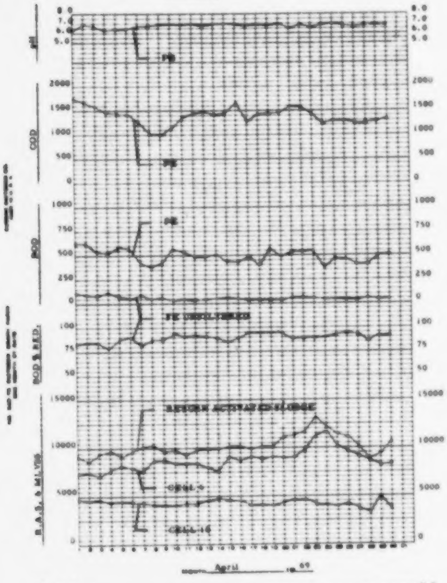
DAY DATE	TOT SUS SOLIDS PE	FE	P/CNT RED	VOLATILE SUS SOLIDS PE	FE	P/CNT RED	UNFILTERED BOD PE	FE	P/CNT RED	FILTERED BOD PE	FE	P/CNT RED	PH	COLOR UNITS FE	FE
01	064	040	37.5				630	080	86.7				7.6		
02	152	050	42.1	100	042	58.0	620	068	89.0						
03	240	072	70.0	160	032	80.0	565	040	92.7	424	032	92.5		368	
04	136	058	57.4	128	046	64.1	525	062	88.2						
05	152	046	69.7	148	046	68.9	572	057	90.0						
06	116	054	53.4	112	046	58.9	558	027	95.0					362	
07	112	038	66.1	104	038	63.5	417	082	80.3				7.5		
08	136	032	76.5	136			380	052	86.3						
09	120	028	76.7				635	052	86.0					237	
10	112	022	80.4		022		576	029	94.9	390	030	92.5			
11	174	074	[illegible]	120			560	066	87.8						
12	128	016	87.5	116	016	87.9	482	034	92.9					361	
13	080	025	68.8	072	015	79.2	487	036	92.6						
14	152	041	73.0	108	033	69.4	507	065	87.2				7.7		
15	160	047	70.6	128	041	68.0	435	086	80.2					341	
16	160	060	62.1	108	043	60.2	420	072	82.9						
17	100	029	71.0				495	034	93.1	413	022	94.7			
18	140	021	85.0	096	020	79.2	400	026	93.5					323	
19	160	042	73.6	104	025	76.0	567	054	90.5						
20	112	045	59.8	080	033	58.8	493	060	87.8						
21	176	044	75.0	132	036	72.7	530	080	84.9				7.6	323	
22	124	046	62.9	112	038	66.1	535	116	78.3						
23	168	112	33.3	120	030	75.0	562	142	74.7						
24	088	080	9.1	080	074		385	142	63.1	285	059	79.3		29[illegible]	
25	104	100	41.3	144	086	40.3	670	152	67.7						
26	112	062	44.6		061		459	131	71.5						
27	120	160		092	244		408	165	59.6						
28	172	336		152	300		400						7.0		
29	116	592		104	574		495	238	47.9						
30	160	776		128	048		505	306	39.4					275	
TOTAL	04024	03279		02044	02590		14701	2404		01520	0143		37.4	02020	
AVG	00134	00109	18.7	00114	00104	6.8	00493	0080	81.7	00380	0036	90.8	7.5	00313	.00
MAX	240	776	87.5	160	648	87.9	630	306	95.0	424	059	94.7	7.7	368	
MIN	064	016	9.1	040	016	25.0	380	026	39.4	285	022	79.3	7.0	237	

04 69 NUTRIENT DATA PROCESS D FORM N2

P H O S P H O R U S

DAY DATE	O R T H O PE	OS	PRF	T O T A L PE	PE	PRF	CELL ID CELLULAR N	P	PER BOD N.P. BOD = 100 N	P
01										
02							5.7	2.7		
03	1.1	327	6.3	3.4	3.9				3.8	1.2
04										
05										
06	.6	141	7.6	1.2	1.7				5.8	1.6
07										
08										
09	.9	322	6.3	4.1	4.9				6.1	1.9
10										
11							6.1	2.0		
12	.9	104	3.8	4.2	4.1				6.1	.8
13										
14										
15	.5	127	2.6	4.2	3.6				4.8	.6
16										
17							9.4	2.1		
18	.5	116	2.0	2.8	2.5				5.2	.5
19										
20										
21	.5	131	2.5	4.1	4.0				4.5	.5
22										
23							6.3	1.8		
24	.1	076	1.7	5.7	3.6				4.8	.5
25										
26										
27	.1	092	1.6	3.0	1.5				3.8	.3
28										
29							9.3	1.9		
30	1.4	061	2.9	4.6	4.8				4.5	.5
TOTAL	6.5	1670	36.2	36.1	35.8		44.3	9.5	51.0	7.5
AV.	.6	0168	3.6	3.8	3.6	.8	6.0	1.9	5.1	.8
MAX	1.4	341	7.6	5.7	6.9		9.4	2.8	6.1	1.6
MIN	.1	061	1.2	1.2	1.5		6.1	1.3	4.1	.3

PROCESS A



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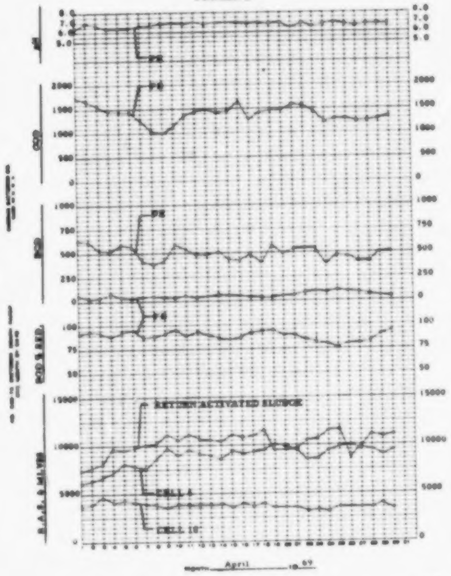
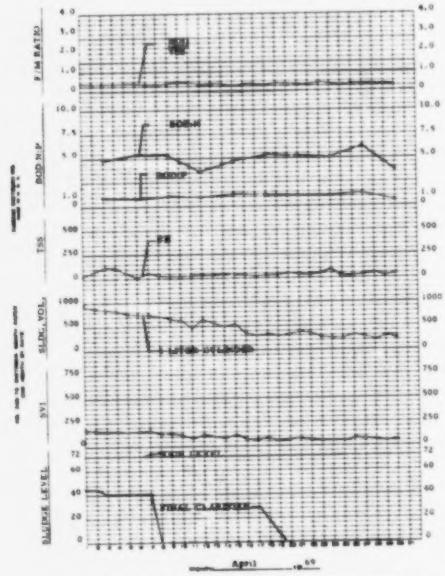
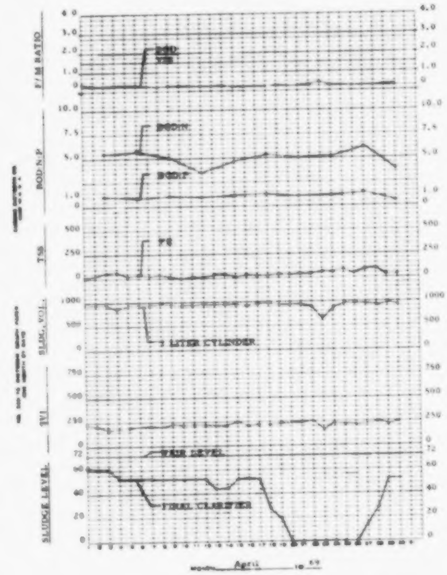
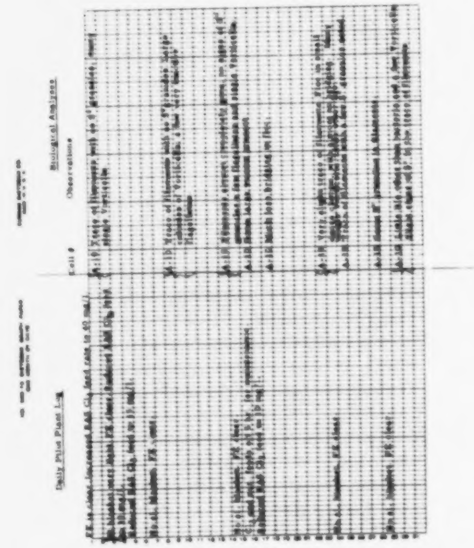
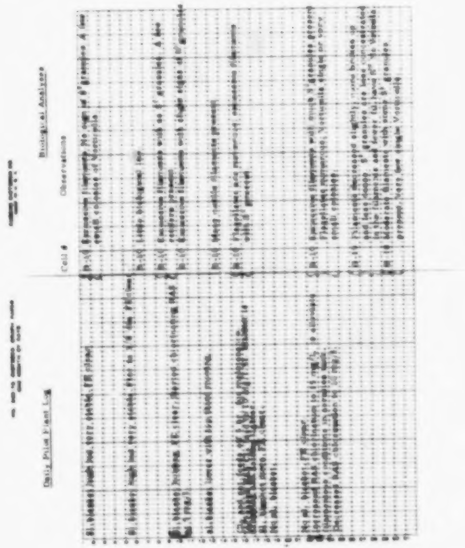
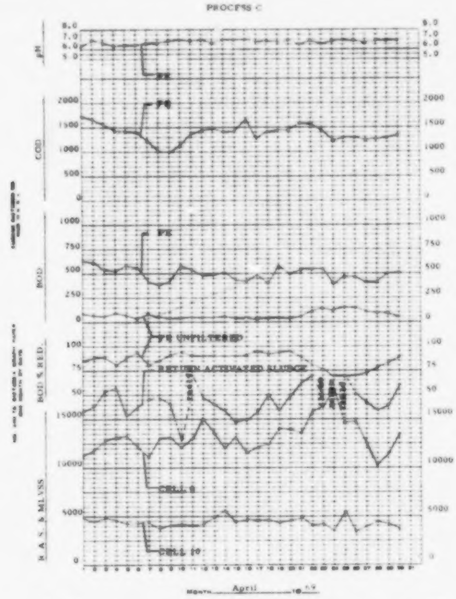


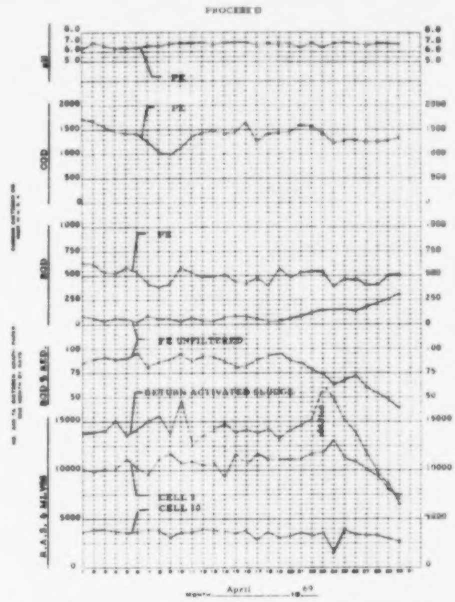


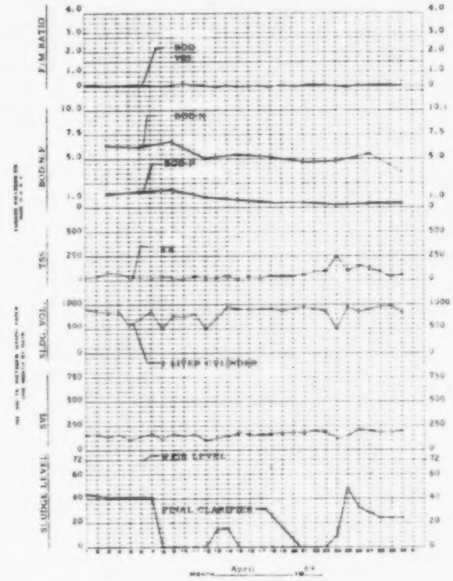


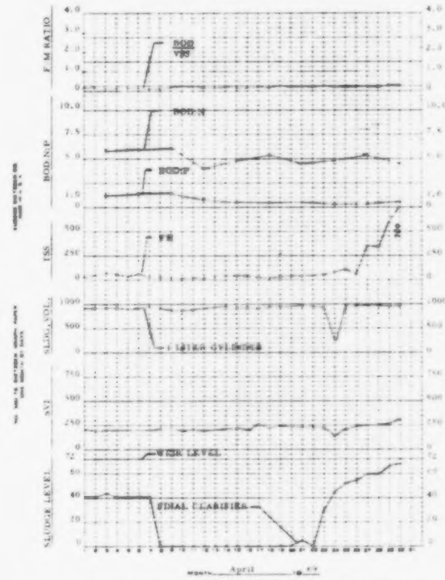

Daily Pilot Plant Log
Biological Analyses
Observations
Cell 5
April 69

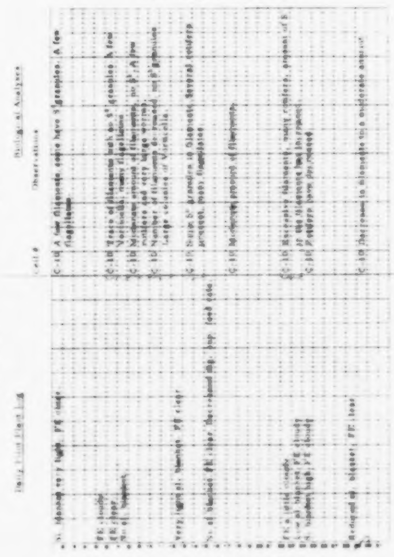

Daily Pilot Plant Log
Biological Analyses
Observations
Cell 4
April 69

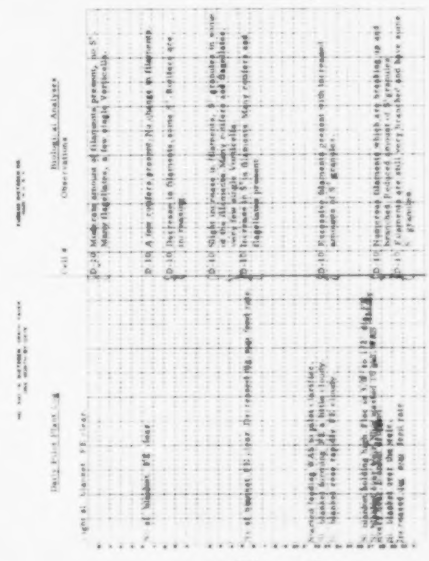

PROCESS C
pH
COD
BOD
BOD % RED.
R.A.S. & MLVSS
PE
PE UNFILTERED
RETURN ACTIVATED SLUDGE
CELL 9
CELL 10
8.0
7.0
6.0
5.0
2000
1500
1000
500
0
1000
750
500
250
100
75
50
15000
10000
5000
MONTH April 19 69


PROCESS D
pH
COD
BOD
BOD % RED.
R.A.S. & MLVSS
PE
PE UNFILTERED
RETURN ACTIVATED SLUDGE
CELL 9
CELL 10
8.0
7.0
6.0
5.0
2000
1500
1000
500
0
1000
750
500
250
100
75
50
15000
10000
5000
MONTH April 19 69


F/M RATIO
BOD/VSS
BOD:N:P
BOD:N
BOD:P
TSS
PE
SLDG. VOL.
1 LITER CYLINDER
SVI
SLUDGE LEVEL
WEIR LEVEL
FINAL CLARIFIER
4.0
3.0
2.0
1.0
0
10.0
7.5
5.0
1.0
500
250
1000
500
750
72
60
40
20
MONTH April 19 69


F/M RATIO
BOD/VSS
BOD:N:P
BOD:N
BOD:P
TSS
PE
SLDG. VOL.
1 LITER CYLINDER
SVI
SLUDGE LEVEL
WEIR LEVEL
FINAL CLARIFIER
4.0
3.0
2.0
1.0
0
10.0
7.5
5.0
1.0
500
250
1000
500
750
72
60
40
20
MONTH April 19 69


Biological Analyses
Observations
Cell #
Daily Final Plant Log
MONTH April 19 69


Biological Analyses
Observations
Cell #
Daily Final Plant Log
MONTH April 19 69

APPENDIX C

QUANTITY AND CHARACTERISTICS OF MUNICIPAL AND PULP MILL EFFLUENTS

QUANTITY AND CHARACTERISTICS OF MUNICIPAL AND PULP MILL WASTES

The proposed quantities of flow from these five major sources were revised several times during the project. A schedule of the flows used to proportionately composite the five wastes for use in the laboratory reactors and the pilot plants is presented on page 347.

The characteristics of the Mill and Metro wastes are presented on page 349; the following facts apply to this Table:

1. Between June, 1967 and February, 1968 mill waste grab samples were delivered to the GBMSD laboratories in small containers.

2. Between February 16, 1968, when the first tank-trailer load of waste was received, and April 16, 1968, the samples used for laboratory analyses were obtained directly from the tank-trailer. After April 16, 1968, all samples of mill wastes were taken from the respective storage tanks after they were filled. This change in sampling procedure was made to obtain the characteristics of the mixture of old and fresh wastes in each of the storage tanks actually being fed to the pilot plants rather than the individual characteristics of each mill waste as it was delivered to the pilot plant site.

3. Data on Mill 1 waste characteristics are restricted to the periods of June 8, 1967 through February 15, 1968 and September 3, 1968 through August 22, 1969; mill waste loads obtained outside these time intervals were not representative due to inadequate mixing of mill storage tank contents prior to discharge into the tank-trailer.

4. The limited number of ammonia, nitrate, ortho phosphorus and total phosphorus analyses presented were obtained between June 16, 1969 and August 12, 1969, with the exception of Mill 2 ammonia analyses and Metro total phosphorus analyses which were obtained uniformly between the dates showin in the Table.

5. The Metropolitan waste characteristics are taken from the monthly data sheets maintained by the GBMSD.

Information on the temperature of the wastes is presented on page 351.

HYDRAULIC FLOWS UTILIZED IN STUDIES, MGD

Date	Mill				Metro	Total
	1	2	3	4		
June 1, 1967	4.0	5.0	7.0	3.0	20.0	39.00
February 6, 1968	4.0	5.0	7.0	2.25	20.0	38.25
February 24, 1969	5.0	5.0	10.5	2.3	23.5	46.30
March 26, 1969	5.0	5.0	10.5	2.5	23.5	46.50
June 23, 1969	5.0	5.0	10.5	0.6	23.5	44.60
August 13, 1969	5.0	5.0	10.5	0.6	30.0	51.10
Sept. 16, 1969	5.0	5.0	13.25	0.6	30.0	53.85
October 20, 1969	5.0	5.0	13.25	0.6	23.5	47.35
Dec. 15, 1969	5.0	5.0	13.25	0.6	23.5	47.35

PHYSICAL AND CHEMICAL CHARACTERISTICS OF MUNICIPAL AND PULP MILL WASTES

Source	Mill No. 1		Mill No. 2			Mill No. 3			Mill No. 4			Metro		
From	6/ 8/67	4/17/68	6/ 8/67	2/16/68	4/17/68	6/ 8/67	2/16/68	4/17/68	6/ 8/67	2/16/68	4/17/68	6/ 8/67	2/16/68	4/17/68
To	2/15/68	12/16/69	2/15/68	4/16/68	12/16/69	2/15/68	4/16/68	12/16/69	2/15/68	4/16/68	12/16/69	2/15/68	4/16/68	12/16/69
pH														
Ave.	4.1	3.9	6.9	6.7	5.7	9.9	9.6	8.6	7.5	7.3	6.9			
Max.	4.7	4.5	8.9	8.8	8.4	11.6	11.0	10.1	9.9	8.5	7.4	8.1	7.9	7.8
Min.	3.4	3.5	4.0	5.0	3.6	6.8	7.0	6.3	7.0	4.6	6.1	6.7	6.8	6.7
Samples	32	61	29	5	57	31	9	87	29	12	66	252	61	609
TSS, mg/l														
Ave.	188	237	230	120	195	208	139	221	189	235	351	253	284	229
Max.	520	416	557	232	578	760	288	476	633	447	1300	524	456	564
Min.	32	64	70	28	38	76	60	56	72	36	60	64	160	68
Samples	31	39	29	6	69	29	11	115	28	17	87	252	61	609
BOD, mg/l														
Ave.	1255	1564	876	841	882	574	624	579	1111	905	1360	336	296	271
Max.	1815	2640	1260	1170	2310	870	1046	1170	2520	1515	6000	491	606	770
Min.	630	645	280	375	480	375	315	225	240	190	675	73	121	72
Samples	32	38	29	8	70	31	13	121	29	20	89	252	61	609
TC, mg/l														
Ave.		1392			942			493			1959			243
Max.		1978			1424			891			3670			440
Min.		705			531			381			771			134
Samples		50			46			84			42			361
NH$_3$, mg/l as N														
Ave.		1.4	127.1		127.2			1.7			1.3			9.2
Max.		2.5	226.6		291.0			3.6			2.0			16.1
Min.		0.4	28.1		57.0			0.4			0.4			3.7
Samples		6	26		52			4			6			6
NO$_3$, mg/l as N														
Ave.		0.2			0.5			0.3			0.3			1.1
Max.		0.6			1.1			0.7			0.4			2.2
Min.		0			0			0			0.2			0.4
Samples		4			4			4			4			4
Ortho - P mg/l as P														
Ave.		0.2			0			0.3			0	7.3*	8.5*	1.3
Max.		0.3			0			0.3			0.1	10.1	11.8	2.1
Min.		0.1			0			0.2			0	3.7	4.9	0.3
Samples		6			5			4			6	15	7	6
Total - P mg/l as P														
Ave.		0.5			0.2			1.6			0.9			10.4
Max.		0.7			0.3			2.1			1.4			21.9
Min.		0.3			0.1			0.9			0.3			1.6
Samples		6			5			4			6			80

*These values are ortho plus condensed phosphorus, not ortho phosphorus only.

TEMPERATURES OF MILL AND METRO WASTES

Source	Temperature, °F		Remarks
	Summer	Winter	
Mill 1	120	80	Estimated values based on limited measurements.
Mill 2	116-122	85-95	Estimated values based on limited measurements. Temperature changes would be gradual.
Mill 3	July High 113 Low 102 Avg. 107	January High 96 Low 79 Avg. 90	Measured values. Hourly variations small due to equalization effect of lagoons. Daily variation of 5° in summer and 15° in winter could be expected.
Mill 4	140	140	Temperature is controlled to a constant value.
Metro			
1965	Max. 76 (August)	Min. 45 (March)	These are trickling filter effluent values. Studies made prior to this project indicate that the primary influent temperature averages approximately 3° higher than the trickling filter effluent temperature.
1966	Max. 78 (Sept.)	Min. 45 (Feb.)	
1967	Max. 76 (Sept.)	Min. 47 (March)	
1968	Max. 78 (August)	Min. 47 (January)	
1969	Max. 78 (August)	Min. 50 (January)	

MINERAL ANALYSES OF MILL AND METRO WASTES

Source	Percent by Weight					Mg/l as Element	
	P	K	Ca	Mg	Na	Al	Ba
Mill 1	<0.0013	<0.0050	0.0240	0.0018	0.0009	1.40	<0.10
Mill 2	<0.0013	<0.0050	0.0075	0.0016	0.0014	0.77	<0.10
Mill 3	<0.0013	<0.0050	0.0130	<0.0005	0.0230	23.00	<0.10
Mill 4	<0.0013	<0.0050	0.0047	0.0009	0.0420	5.80	0.21
Metro	<0.0013	<0.0050	0.0047	0.0018	0.0140	1.30	<0.10

Source	Mg/l as Element						
	Fe	Sr	B	Cu	Zn	Mn	Cr
Mill 1	2.5	0.36	<0.05	<0.05	0.16	<0.10	<0.15
Mill 2	0.5	0.36	<0.05	<0.05	0.06	<0.10	<0.15
Mill 3	1.1	0.36	0.48	<0.05	0.13	<0.10	<0.15
Mill 4	3.3	0.36	0.08	0.06	0.17	0.36	<0.15
Metro	1.8	0.67	0.19	<0.05	0.42	<0.10	<0.15

Method of Analyses - Journal of the A.O.A.C., Vol. 51, Number 5, 1968, pp. 1003-1010.

Grab samples of the five wastes (the mill samples were taken from the storage tanks) were analyzed for mineral content in August, 1969. The results of these tests are presented on page 352. The values shown must be considered only as indicative of the range expected for the given parameter as they are based on one sample.

Miscellaneous analyses conducted on single grab samples are presented as follows. These values must also be considered only as indicative of the range expected for the given parameter as they are based on one sample.

MISCELLANEOUS ANALYSES ON MILL AND METRO WASTES

Date	6/8/67	6/8/67		8/28/69		9/24/69
Source	Total Organic Nitrogen	Volatile Acids	pH	Methyl Orange Alkalinity	Chloride	Sulfate
	mg/l as N	mg/l as acetic		mg/l as $CaCO_3$	mg/l as Cl	mg/l as SO_4
Mill 1	3.0	759	3.7	0	105	2645
Mill 2	5.4	157	6.0	200	87	2048
Mill 3	11.6	169	9.7	400	247	377
Mill 4	9.9	381	6.7	720	40	53
Metro			7.0	248	274	596

APPENDIX D

EXPERIMENTAL DATA

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PILOT PLANT LABORATORY DATA - PHASE IV

The following comments apppy to the laboratory data sheets:

1. The data are presented in the vertical order of average value, maximum value, minimum value.
2. All total and volatile suspended solids are expressed as mg/l.
3. The final clarifier sludge level is expressed in inches.
4. The cellular nitrogen and phosphorus values are expressed as percent by weight.
5. The settled sludge volume is expressed in milliliters.
6. All nitrogen analyses are reported in mg/l as N.
7. All phosphorus analyses are reported in mg/l as P.
8. PEF = primary effluent fortified; this is the primary effluent after nutrient addition.
9. BOD is reported as mg/l.

GBMSD Industrial-Municipal Research Project
Primary Clarifier

		Primary Influent Flow Liters/Day						Influent				Effluent									
		Mills							mg/l				mg/l		% Red.	mg/l	% Red.	mg/l		BOD	Color
Month	Year	1	2	3	4	MSD	Total	pH	TSS	VSS	BOD	pH	TSS	VSS	TSS	BOD	BOD	COD	TC	TC	Units
Aug.	69	1917	1797	4025	229	8718	16687	6.7	220	192	481	6.6	160	142	27.3	457	5.0	1023	513	.89	256
		1933	1933	4058	231	11555	19710	7.1	232	264	600	7.1	220	200	46.4	548	15.7	1374	590	1.07	332
		1450	0	3043	173	5452	11568	6.4	148	124	323	6.4	96	104	0	330	0	672	425	.62	54
Sept.	69	1263	1263	2682	152	8367	13727	6.8	206	169	434	6.8	126	104	38.8	401	7.6	830	485	.83	256
		1266	1266	3180	152	10912	16254	7.1	352	312	565	7.0	200	180	68.2	510	27.3	1168	560	1.07	332
		1200	1200	2658	144	6392	11734	6.5	100	84	295	6.5	56	40	8.0	285	0	566	410	.62	175
Oct.	69	1440	1440	3770	173	8163	14987	6.8	192	151	457	6.8	124	100	35.4	434	5.0	813	455	.96	243
		1843	1843	4896	223	11109	19914	7.0	492	372	600	7.0	192	152	61.0	550	20.7	1187	560	1.28	342
		1200	1200	3180	144	5257	11515	6.4	112	104	325	6.4	72	52	0	340	0	605	390	.67	163
Nov.	69	1843	1843	4896	223	7138	15943	6.8	253	192	480	6.7	151	114	40.3	466	2.9	1029	476	1.01	248
		1843	1843	4896	223	10193	18998	7.1	372	284	612	7.1	224	160	66.7	629	27.4	1225	870	1.94	337
		1843	1843	4896	223	2233	11038	5.2	124	88	346	6.5	92	60	11.8	300	0	790	300	.68	170
Dec.	69	1805	1597	4794	218	5188	13602	6.7	250	189	540	6.7	203	156	18.8	492	8.9	1229	499	.97	276
		1843	1843	4896	223	7714	14676	6.9	404	312	670	7.1	588	432	50.8	600	18.8	1568	570	1.18	373
		1267	0	3366	153	3602	10981	6.4	104	88	340	6.3	100	76	0	326	0	908	400	.80	220

GBMSD Industrial-Municipal Research Project
Process A

Month	Year	Reaeration Sec.			Contact Sec.			Return and Waste Sludge			Digester Supernatant						Set Sl. Volume		30 Min. SVI	Clar. sludge level	F/M Ratio	
		mg/l									mg/l			L/D added	grams TSS added	DS-TSS / PE-TSS	10 Min.	30 Min.			TC / VSS	BOD / VSS
		TSS	VSS	%	TSS	VSS	%	TSS	VSS	%	TSS	VSS	BOD									
8	69	12475	10921	87.5	4293	3776	88.0	12764	11191	87.7							924	736	173	0	.34	.31
		16452	14612	89.1	4888	4252	91.3	16012	14116	89.1							980	930	234	6	.45	.38
		9836	8528	85.3	3472	3164	85.2	9740	8384	85.5							640	360	85	0	.25	.20
9	69	12338	10983	89.0	3750	3370	89.9	13228	11823	89.4							794	587	155	0	.37	.28
		15000	13376	91.7	4280	3848	94.6	15544	13996	90.8							980	930	252	0	.43	.40
		9972	8900	86.3	2756	2488	84.0	10396	9236	87.7							400	300	75	0	.26	.14
10	69	13024	11543	88.6	4083	3662	89.7	13874	12354	89.0							348	264	64	0	.32	.25
		15940	14364	91.7	4920	4500	94.1	17068	15288	91.5							520	375	87	0	.43	.38
		9740	8656	86.2	3028	2784	86.6	10776	9492	85.9							210	170	47	0	.23	.09
11	69	15585	12871	82.6	4451	3718	83.5	16456	13650	82.9							375	281	64	0	.28	.27
		20048	16384	87.1	5680	4764	87.9	19440	16076	85.7							465	350	75	0	.44	.37
		11912	9772	79.1	3616	3012	80.4	13692	11232	79.4							270	200	53	0	.17	.16
12	69	15635	13104	83.8	4203	3542	84.3	15357	12902	84.0							379	282	66	0	.25	.24
		18516	15484	85.6	5180	4312	86.6	16920	14076	85.8							570	380	84	0	.28	.32
		14124	11744	81.3	3204	2728	82.0	12788	10664	77.0							260	200	55	0	.16	.13

GBMSD Industrial-Municipal Research Project
Process B

Month	Year	Reaeration Sec.			Contact Sec.			Return and Waste Sludge			Digester Supernatant						Set Sl. Volume		30	Clar.	F/M Ratio	
		mg/l									mg/l			L/D	grams TSS	DS-TSS	10	30	Min.	sludge	TC	BOD
		TSS	VSS	%	TSS	VSS	%	TSS	VSS	%	TSS	VSS	BOD	added	added	PE-TSS	Min.	Min.	SVI	level	VSS	VSS
8	69	9290	8108	87.3	4065	3547	87.3	9648	8455	87.6							891	790	190	12	.38	.34
		11708	10004	89.2	5012	4300	90.8	11764	9968	89.4							995	990	247	56	.62	.57
		6900	6156	84.6	2980	2592	84.1	7770	6822	84.7							230	180	60	0	.20	.16
9	69	10584	9193	86.9	4178	3647	87.3	11568	10079	87.1							646	426	101	0	.40	.34
		13356	11604	89.8	4824	4224	91.1	13888	12072	88.6							950	800	189	0	.71	.52
		6452	5744	.4	3192	2848	82.5	7592	6604	86.0							260	200	63	0	.26	.22
10	69	13718	12006	.5	4235	3728	88.0	14578	12801	87.8							322	240	57	0	.31	.29
		15348	13636	.8	5248	4696	91.3	16456	14492	93.5							460	340	75	0	.40	.39
		11076	9728	.4	3644	3200	80.3	11344	10080	86.0							220	170	40	0	.24	.23
11	69	13967	12087	.5	4161	3619	87.0	15240	13079	86.0							396	282	68	0	.29	.28
		16332	14112	.5	4840	4312	90.0	18868	15984	88.3							750	505	104	0	.47	.38
		11804	10248	.1	3536	3040	82.8	9332	7964	83.5							225	170	47	0	.18	.18
12	69	14569	12125	.2	4295	3603	83.9	16344	13676	83.7							781	605	140	0	.26	.25
		17140	14096	.4	4904	4040	85.5	18900	16528	87.4							940	840	193	0	.31	.34
		12740	10704	.1	3616	3048	82.4	13100	11012	82.4							400	300	69	0	.17	.14

GBMSD Industrial-Municipal Research Project

Process C

Month	Year	Reaeration Sec.			Contact Sec.			Return and Waste Sludge			Digester Supernatant						Set Sl. Volume		30	Clar.	F/M Ratio	
		mg/l									mg/l			L/D	grams TSS	DS-TSS	10	30	Min.	sludge	TC	BOD
		TSS	VSS	%	TSS	VSS	%	TSS	VSS	%	TSS	VSS	BOD	added	added	PE-TSS	Min.	Min.	SVI	level	VSS	VSS
8	69	11765	10384	88.3	4243	3763	88.7	12293	10896	88.6							948	908	218	49	.36	.32
		16132	14040	90.6	5288	4668	91.3	16488	14448	90.4							995	975	298	68	.54	.51
		8436	7628	86.4	1996	1792	85.4	9636	8620	86.6							440	310	103	23	.23	.18
9	69	11391	10113	88.8	4055	3583	88.4	12724	11309	88.9							878	789	194	8	.38	.32
		14188	13088	92.2	6080	4736	92.1	19208	16992	98.9							985	970	260	43	.50	.52
		9040	8144	84.8	2044	1800	77.9	10356	9148	86.6							300	230	89	0	.29	.20
10	69	12890	11006	85.4	4455	3906	87.7	15312	13193	86.2							844	712	164	0	.32	.31
		16588	13836	88.3	5628	5112	96.7	21128	18424	88.0							980	960	340	0	.43	.44
		10044	8544	76.1	1296	1244	84.4	10520	9056	83.4							300	230	69	0	.23	.23
11	69	14144	11852	83.8	4307	3620	84.0	14869	12545	84.4							532	381	91	0	.29	.29
		15932	13708	87.1	5640	4796	88.2	19324	16184	86.8							955	880	249	0	.46	.40
		11857	9872	78.7	1684	1408	75.9	9060	7544	81.7							300	220	53	0	.19	.18
12	69	14233	12107	85.1	4280	3608	84.3	14317	12095	84.5							783	605	140	0	.26	.26
		15948	14932	94.7	4796	4108	85.7	15912	13264	85.4							960	850	191	0	.35	.38
		11156	9312	83.0	3336	2768	82.9	11584	9752	83.4							360	270	74	0	.20	.16

GBMSD Industrial-Municipal Research Project
Process D

Month	Year	Reaeration Sec.			Contact Sec.			Return and Waste Sludge			Digester Supernatant						Set Sl. Volume		30 Min. SVI	Clar. sludge level	F/M Ratio	
		mg/l									mg/l			L/D added	grams TSS added	DS-TSS / PE-TSS	10 Min.	30 Min.			TC / VSS	BOD / VSS
		TSS	VSS	%	TSS	VSS	%	TSS	VSS	%	TSS	VSS	BOD									
8	69	9880	8690	88.0	4056	3596	88.7	10773	9529	88.5							962	898	224	14	.35	.32
		12468	10904	91.8	5180	4580	94.9	13204	11868	93.7							990	965	306	69	.67	.54
		6784	6228	81.9	2692	2468	81.0	6676	6136	85.7							880	750	182	0	.17	.13
9	69	9939	8315	89.0	3756	3355	89.3	10180	9110	89.5							756	593	160	1	.44	.36
		13440	11892	91.7	4496	3980	94.6	14152	12672	95.6							980	920	261	10	.60	.53
		6376	5580	86.9	2668	2428	80.9	6860	6116	85.9							260	200	54	0	.31	.23
10	69	12343	10747	87.1	4218	3718	88.1	13242	11540	87.1							468	357	84	0	.33	.32
		14240	12508	91.7	5456	4832	96.8	15260	13248	92.6							930	810	188	0	.42	.46
		9532	8484	83.4	3728	3188	83.4	10428	9268	84.7							230	180	44	0	.24	.23
11	69	13807	11489	83.2	4444	3716	83.6	14630	12205	83.4							530	351	79	0	.30	.29
		16688	14296	91.5	5384	4420	89.4	17444	14428	94.1							920	490	100	0	.54	.41
		11488	9692	79.4	3760	3132	79.4	9416	7624	81.0							350	260	63	0	.17	.17
12	69	13202	10971	83.1	4356	3647	83.7	13176	11077	84.1							398	278	63	0	.27	.27
		14864	12284	85.1	5100	4236	85.9	16588	13936	88.5							600	350	78	0	.32	.34
		11932	9912	82.1	3296	2756	80.7	7664	6460	82.3							190	140	42	0	.18	.15

GBMSD Industrial-Municipal Research Project
Process A

Supplemental Operating Data										Final Effluent mg/l													
Month	Year	Feed bypass L/D	Q L/D	RAS L/D	R/Q Ratio	WAS L/D	Sol. Wasted grams/day TSS	Sol. Wasted grams/day VSS	F.C. TSS load #/sf/d	Total Sus. Solids PE	Total Sus. Solids FE	Total Sus. Solids %red	Volatile Sus. Solids PE	Volatile Sus. Solids FE	Volatile Sus. Solids %red	Unfiltered BOD PE	Unfiltered BOD FE	Unfiltered BOD %red	Filtered BOD PE	Filtered BOD FE	Filtered BOD %red	pH	Color Units FE
8	69	0	4216	1632	.39	61.2	785	688	17.7	160	39	75.6	142	35	75.4	457	31	93.2	352	15	95.7	7.6	225
		0	4928	2448	.66	102.2	1293	1151	21.7	220	114	97.6	200	96	86.7	548	51	97.4	413	25	96.9	7.7	396
		0	3501	950	.22	0	0	0	12.1	96	4	44.1	104	21	42.9	330	10	90.2	308	10	93.9	7.5	40
9	69	0	4642	1325	.29	45.8	623	556	15.7	138	64	53.6	122	53	56.6	369	62	83.2	308	29	90.6	7.6	216
		0	5701	1507	.38	121.1	1649	1453	19.8	232	144	86.5	212	110	84.7	518	225	95.3	368	41	94.4	7.7	232
		0	3806	1066	.22	0	0	0	10.5	62	24	0	66	22	0	213	10	34.8	278	16	86.3	7.2	130
10	69	0	6311	1861	.31	41.2	609	543	23.5	128	59	53.9	106	50	52.8	362	58	84.0	290	18	93.8	7.6	190
		0	11989	2549	.41	147.6	2519	2257	42.2	372	138	82.3	308	106	79.7	530	143	93.2	417	23	95.3	7.7	275
		0	3516	1152	.19	0	0	0	13.5	50	19	0	48	14	0	150	30	56.1	158	14	89.9	7.5	113
11	69	0	3986	1195	.30	70.4	1146	949	16.2	151	81	46.4	114	58	49.1	466	45	90.3	427	24	94.4	7.4	238
		0	4750	1444	.42	166.6	2712	2222	21.5	224	160	83.8	160	156	75.0	629	75	95.3	476	29	95.9	7.5	340
		0	2760	1037	.26	15.1	294	240	10.9	92	24	0	60	20	0	300	18	84.4	409	17	92.9	7.2	170
12	69	0	3401	1117	.33	78.5	1215	1025	13.3	203	71	65.0	156	50	67.9	492	68	86.2	484			7.5	262
		0	3669	1212	.43	117.3	1699	1458	16.5	588	112	85.0	432	84	83.3	600	153	92.3	484			7.6	305
		0	2745	1049	.29	34.1	436	364	10.7	100	32	37.1	76	16	32.7	326	34	74.5	484			7.4	180

GBMSD Industrial-Municipal Research Project

Process B

Supplemental Operating Data										Final Effluent														
										mg/l														
Month	Year	Feed bypass	Q	RAS	R/Q Ratio	WAS	Sol. Wasted grams/day		F.C. TSS load	Total Sus. Solids			Volatile Sus. Solids			Unfiltered BOD			Filtered BOD			pH	Color Units
		L/D	L/D	L/D		L/D	TSS	VSS	#/sf/d	PE	FE	%red	PE	FE	%red	PE	FE	%red	PE	FE	%red		FE
8	69	0	4203	2486	.59	41.6	409	359	19.1	160	74	53.8	142	63	55.6	457	47	89.7	352	15	95.7	7.6	210
		0	4928	3197	.85	121.1	1356	1170	25.6	220	134	90.4	200	114	94.2	548	82	96.7	413	23	97.2	7.8	318
		0	3501	1872	.42	0	0	0	13.5	96	13	25.8	104	7	28.8	330	11	81.0	308	10	94.4	7.5	43
9	69	0	4576	2028	.44	20.2	249	216	19.3	126	31	75.4	104	26	75.0	401	35	91.3	352	16	95.5	7.7	197
		0	5418	3099	.62	128.7	1638	1419	22.9	200	80	91.7	180	46	93.3	510	62	94.5	432	22	97.0	7.8	293
		0	3911	1537	.32	0	0	0	15.2	56	11	31.0	40	8	42.5	285	19	85.4	304	10	92.8	7.4	153
10	69	0	4476	1379	.31	52.0	763	670	17.4	124	37	70.2	100	30	70.0	434	42	90.3	344	16	95.3	7.8	191
		0	5713	1495	.39	128.7	2090	1844	22.0	192	102	87.0	152	65	89.1	550	69	96.4	417	20	96.6	7.9	232
		0	3516	1276	.23	0	0	0	13.3	72	13	31.1	52	10	32.3	340	14	82.1	248	12	91.9	7.7	175
11	69	0	3986	1230	.31	63.1	963	826	15.2	151	44	70.9	114	31	72.8	466	41	91.2	427	17	96.0	7.7	215
		0	4750	1385	.46	140.1	2304	1924	18.4	224	94	91.3	160	78	96.9	629	66	97.3	476	20	97.3	7.8	230
		0	2760	1094	.25	7.6	121	104	10.4	92	8	24.0	60	2	45.0	300	10	81.7	409	11	95.6	7.5	138
12	69	0	3401	1152	.34	64.5	1048	875	13.7	203	101	50.2	156	70	55.1	492	88	82.1	484			7.7	212
		0	3669	1213	.39	140.1	2027	1679	15.7	588	376	86.4	432	182	94.4	600	174	93.3	484			7.8	275
		0	2745	1082	.29	24.6	427	357	11.3	100	18	0	76	6	0	326	30	71.0	484			7.6	153

GBMSD Industrial-Municipal Research Project
Process C

Supplemental Operating Data										Final Effluent													
										mg/l													
Month	Year	Feed bypass L/D	Q L/D	RAS L/D	R/Q Ratio	WAS L/D	Sol. Wasted grams/day		F.C. TSS load	Total Sus. Solids			Volatile Sus. Solids			Unfiltered BOD			Filtered BOD			pH	Color Units
							TSS	VSS	#/sf/d	PE	FE	%red	PE	FE	%red	PE	FE	%red	PE	FE	%red		FE
8	69	0	4203	2100	.50	74.5	899	797	18.7	160	58	63.8	142	53	62.7	457	39	91.5	352	20	94.3	7.7	208
		0	4928	2724	.66	212.0	2400	2145	24.4	220	168	88.7	200	148	91.4	548	120	97.4	413	28	96.8	7.8	358
		0	3501	1267	.27	0	0	0	9.5	96	14	12.5	104	10	20.2	330	10	77.7	308	10	92.5	7.6	40
9	69	0	4576	1792	.39	49.6	619	551	18.0	126	58	54.0	104	52	50.0	401	46	88.5	352	23	93.5	7.7	219
		0	5418	2196	.50	196.8	2528	2254	26.7	200	144	87.5	180	128	87.1	510	112	93.3	432	31	95.3	7.8	315
		0	3911	1330	.25	3.8	45	40	9.7	56	16	0	40	10	0	285	24	74.5	304	16	90.6	7.6	165
10	69	0	4476	1550	.35	52.5	844	729	18.8	124	44	64.5	100	36	64.0	434	48	88.9	344	14	95.9	7.7	204
		0	5713	1805	.46	132.5	2578	2258	25.4	192	112	85.7	152	92	85.0	550	93	95.4	417	19	98.1	7.8	260
		0	3516	1252	.27	0	0	0	5.1	72	17	0	52	16	0	340	20	76.8	248	8	92.3	7.6	180
11	69	0	3986	1160	.30	64.7	939	790	15.5	151	40	73.5	114	30	73.7	466	36	92.3	427	11	97.4	7.7	221
		0	4750	1556	.41	143.8	2108	1772	20.6	224	88	89.9	160	60	87.5	629	58	96.6	476	13	98.3	7.8	317
		0	2760	998	.23	0	0	0	6.6	92	15	37.1	60	112	37.5	300	14	80.7	409	8	96.8	7.5	163
12	69	0	3401	1084	.32	60.4	876	740	13.5	203	58	71.4	156	41	73.7	492	51	89.6	484	29	94.0	7.7	262
		0	3669	1220	.39	106.0	1445	1204	15.6	588	144	89.5	432	126	90.7	600	92	94.8	484	29	94.0	7.8	305
		0	2745	997	.30	7.6	93	79	8.9	100	18	10.0	76	10	14.9	326	23	84.7	484	29	94.0	7.6	185

GBMSD Industrial-Municipal Research Project

Process D

Supplemental Operating Data										Final Effluent mg/l													
Month	Year	Feed bypass L/D	Q L/D	RAS L/D	R/Q Ratio	WAS L/D	Sol. Wasted grams/day TSS	Sol. Wasted grams/day VSS	F.C. TSS load #/sf/d	Total Sus. Solids PE	Total Sus. Solids FE	Total Sus. Solids %red	Volatile Sus. Solids PE	Volatile Sus. Solids FE	Volatile Sus. Solids %red	Unfiltered BOD PE	Unfiltered BOD FE	Unfiltered BOD %red	Filtered BOD PE	Filtered BOD FE	Filtered BOD %red	pH	Color Units FE
8	69	0	4203	2217	.53	54.8	615	548	18.3	160	43	73.1	142	39	72.5	457	41	91.0	352	21	94.0	7.6	201
		0	4928	3341	.75	166.6	2094	1963	24.9	220	101	93.4	200	80	87.5	548	72	97.4	413	30	96.9	7.7	332
		0	3501	1382	.36	0	0	0	13.2	96	10	48.5	104	16	52.4	330	10	82.2	308	11	90.6	7.5	33
9	69	0	4576	2176	.48	19.1	218	195	17.7	126	87	31.0	104	74	28.8	401	70	82.5	352	31	91.2	7.7	217
		0	5418	2874	.70	83.3	1074	947	21.7	200	236	77.0	180	168	86.1	510	228	94.0	432	39	94.4	7.8	323
		0	3911	1670	.32	0	0	0	13.1	56	22	0	40	10	0	285	25	48.2	304	24	87.8	7.5	125
10	69	0	4476	1651	.37	42.9	573	499	18.1	124	51	58.9	100	44	56.0	434	45	89.6	344	15	95.6	7.7	206
		0	5713	2128	.49	87.1	1297	1140	23.5	192	144	88.9	152	100	85.7	550	82	95.1	417	20	97.8	7.8	275
		0	3516	1282	.28	0	0	0	14.3	72	14	22.9	52	20	26.7	340	19	79.3	248	8	92.7	7.7	190
11	69	0	3986	1109	.28	56.8	841	700	15.9	151	28	81.5	114	20	82.5	466	31	93.3	427	12	97.2	7.6	218
		0	4750	1326	.39	136.3	2086	1704	18.7	224	54	93.9	160	42	95.3	629	48	97.3	476	14	97.7	7.7	305
		0	2760	998	.24	0	0	0	11.1	92	8	60.3	60	4	64.3	300	10	84.0	409	10	96.6	7.6	163
12	69	0	3401	1034	.30	66.9	876	737	13.5	203	35	82.8	156	26	83.3	492	21	95.7	484	9	98.1	7.7	251
		0	3669	1133	.39	117.3	1531	1291	16.0	588	88	95.2	432	72	92.9	600	36	98.2	484	9	98.1	7.8	290
		0	2745	945	.26	26.5	360	297	10.2	100	14	45.0	76	7	51.4	326	9	92.0	484	9	98.1	7.6	180

GBMSD Industrial-Municipal Research Project
Process A

Nutrient Data															
		NH_3 - N mg/l as N				NO_3 - N mg/l as N		Ortho-P mg/l as P			PEF BOD:N:P BOD=100		Cell 10 Cellular	
Month	Year	PE	PEF	DS	RT	C-10	RT	PE	PEF	DS	N	P	% N	% P
8	69	16.5	17.7		9.0	2.0	1.5	1.7	2.4		3.8	.5	9.3	2.3
		25.6	25.6		19.7	4.4	2.6	2.8	3.4		5.4	.8	11.7	2.8
		4.8	4.8		2.6	.4	.4	.5	1.3		1.5	.3	7.7	1.9
9	69	22.5	22.5		13.7	1.7	1.4	4.5	4.7		6.2	1.3	9.7	2.5
		27.3	27.3		25.2	3.7	3.7	5.3	5.7		11.1	2.3	10.0	2.9
		16.2	16.2		1.4	.1	.1	3.6	4.0		3.6	.8	9.4	2.2
10	69	15.6	19.3		7.9	1.0	1.0	1.7	2.0		5.3	.6	10.0	2.3
		25.5	34.1		21.9	4.3	4.7	5.0	5.0		8.4	1.8	13.2	3.0
		7.2	7.2		.7	0	0	.6	.6		2.8	.2	8.7	2.1
11	69	30.6	37.2		25.9	2.8	1.2	1.6	1.8		8.5	.4	6.4	1.8
		49.3	55.9		44.3	18.7	2.5	3.7	2.4		14.2	.7	9.4	2.4
		10.7	16.3		15.1	0	0	.2	1.6		3.5	.1	4.4	1.4
12	69	12.7	20.7		20.9	0	.6	1.5	4.9		4.4	1.0	7.4	2.1
		19.3	29.8		31.8	0	1.8	2.7	8.3		6.0	1.7	8.9	2.4
		1.8	8.5		11.1	0	0	.5	1.0		1.9	.2	5.9	1.7

GBMSD Industrial-Municipal Research Project

Process B

Nutrient Data

Month	Year	NH_3 - N mg/l as N				NO_3 - N mg/l as N		Ortho-P mg/l as P			PEF BOD:N:P BOD=100		Cell 10 Cellular	
		PE	PEF	DS	RT	C-10	RT	PE	PEF	DS	N	P	% N	% P
8	69	16.5	17.7		5.9	1.8	1.6	1.7	2.5		3.8	.5	8.8	2.3
		25.6	25.6		15.0	3.3	2.9	2.8	3.4		5.4	.8	9.6	2.7
		4.8	4.8		1.7	.7	.7	.5	1.4		1.5	.3	7.1	1.8
9	69	19.1	23.7		2.9	2.3	4.3	2.9	3.2		5.8	.8	9.0	2.3
		23.7	27.6		6.8	5.0	15.8	3.8	3.8		8.1	.9	9.4	2.6
		15.3	19.4		1.1	1.1	0	2.2	2.2		4.4	.7	8.7	2.2
10	69	15.6	23.0		4.1	1.4	3.2	1.7	1.7		5.2	.4	9.6	2.3
		18.0	49.9		16.2	4.7	12.6	2.8	2.8		11.7	.5	12.2	2.4
		14.4	17.3		.7	0	0	.8	1.0		3.2	.3	8.3	2.2
11	69	30.6	37.5		22.7	3.2	3.3	1.6	1.9		8.5	.4	6.7	1.9
		49.3	56.8		28.9	19.1	12.9	3.7	2.8		14.0	.7	9.1	2.9
		10.7	16.8		14.4	.4	0	.2	.5		3.6	.1	5.2	1.3
12	69	12.7	20.8		18.5	.5	1.2	1.5	3.7		4.4	.8	6.7	1.9
		19.3	31.3		36.1	1.4	2.9	2.7	6.7		6.7	1.3	8.1	2.3
		1.8	9.2		3.4	0	0	.5	.9		1.6	.2	5.2	1.4

GBMSD Industrial-Municipal Research Project

Process C

Nutrient Data														
		NH_3 - N mg/l as N				NO_3 - N mg/l as N		Ortho-P mg/l as P			PEF BOD:N:P BOD=100		Cell 10 Cellular	
Month	Year	PE	PEF	DS	RT	C-10	RT	PE	PEF	DS	N	P	% N	% P
8	69	16.5	19.8		12.5	1.7	1.6	1.7	2.7		4.3	.6	10.0	2.2
		25.6	28.0		50.4	2.2	3.3	2.8	3.7		9.9	.9	11.8	2.9
		4.8	4.8		1.1	.3	0	.5	1.4		1.5	.3	8.9	1.8
9	69	19.1	23.7		21.8	1.7	1.1	2.9	4.7		5.8	1.2	11.3	2.5
		23.7	28.2		41.7	3.6	2.6	3.8	6.0		8.3	1.7	15.7	3.4
		15.3	20.3		12.2	.7	.1	2.2	3.5		4.3	.7	9.6	2.1
10	69	15.6	22.7		7.2	.8	1.0	1.7	2.5		5.2	.6	8.8	2.6
		18.0	41.4		41.7	3.6	2.9	2.8	4.2		9.7	.8	10.4	2.7
		14.4	18.0		.4	0	0	.8	1.7		3.3	.4	7.8	2.3
11	69	30.6	39.1		24.1	1.2	1.1	1.6	4.7		8.9	1.1	7.0	2.6
		49.3	56.0		27.1	3.6	7.1	3.7	7.8		14.7	1.9	8.4	2.8
		10.7	16.3		18.3	0	0	.2	1.6		3.5	.3	5.7	2.3
12	69	12.7	20.8		19.6	.4	.6	1.5	5.0		4.4	1.0	7.5	2.5
		19.3	29.4		29.6	1.4	1.1	2.7	9.0		5.9	1.7	7.8	2.9
		1.8	8.9		6.4	0	0	.5	1.1		2.0	.2	6.1	2.1

GBMSD Industrial-Municipal Research Project

Process D

Nutrient Data														
		NH_3 - N mg/l as N				NO_3 - N mg/l as N		Ortho-P mg/l as P			PEF BOD:N:P BOD=100		Cell 10 Cellular	
Month	Year	PE	PEF	DS	RT	C-10	RT	PE	PEF	DS	N	P	% N	% P
8	69	16.5	19.9		9.4	1.7	1.7	1.7	2.8		4.3	.6	9.5	2.4
		25.6	28.4		26.3	4.0	4.0	2.8	3.8		7.0	.9	9.8	2.9
		4.8	4.8		1.5	.4	.7	.5	1.4		1.5	.3	9.1	1.9
9	69	19.1	23.7		15.5	1.3	1.3	2.9	4.7		5.8	1.2	9.5	2.2
		23.7	27.8		23.0	3.3	4.4	3.8	6.0		8.1	1.6	10.0	2.7
		15.3	20.3		6.1	.7	0	2.2	3.4		4.2	.7	8.6	1.9
10	69	15.6	22.2		7.0	.7	1.4	1.7	2.5		5.1	.5	9.3	2.6
		18.0	40.5		18.3	1.8	11.2	2.8	4.0		9.5	.7	9.8	2.9
		14.4	17.3		.7	0	0	.8	1.6		3.3	.4	8.3	2.2
11	69	30.6	39.1		23.0	1.5	2.7	1.6	4.5		8.9	1.0	6.6	2.9
		49.3	56.0		25.7	7.1	20.7	3.7	6.9		14.7	1.9	7.8	3.5
		10.7	17.6		20.1	0	0	.2	2.6		3.7	.5	4.7	2.5
12	69	12.7	22.0		21.2	1.4	2.6	1.5	6.0		4.6	1.2	7.3	3.0
		19.3	31.4		31.1	2.9	5.0	2.7	8.3		6.7	1.6	9.0	3.3
		1.8	8.7		6.4	0	.4	.5	4.3		1.9	.7	5.5	2.7

APPENDIX E

SOLIDS HANDLING STUDIES

LABORATORY DATA

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SOLIDS HANDLING STUDIES - LAB DATA - INDEX

Centrifugation Solid Bowl Basket	Sharples Equipment Division
Dissolved Air Flotation	Rex Chainbelt, Inc. The Eimco Corporation
Gravity Thickening	Dorr-Oliver, Inc. The Eimco Corporation Walker Process Equipment
Heat Treatment	BSP Corporation Dorr-Oliver, Inc. Zimpro, Inc.
Low Pressure Oxidation	Zimpro, Inc.
Pressure Filtration	Beloit-Passavant Corporation
Vacuum Filtration	The Eimco Corporation Walker Process Equipment
FE Microscreening	Beloit-Passavant Corporation Crane-Glenfield, Inc. Southwestern Engr. Co.

SOLIDS HANDLING STUDIES - LAB DATA - FOOTNOTES

a. "S" and "T" denotes "Sampled By" and "Tested By", respectively; We = GBMSD; They = Manufacturer

b. 5-day BOD

c. Ammonia nitrogen as N

d. Total ortho phosphorus as P

e. Total phosphorus as P

E. Estimated value

f. "(13:1)" represents the ratio of WAS to primary clarifier sludge, by volume

g. Suffix "C" indicates the use of chemical admixtures; the chemicals and feed rates used are listed on page 374.

h. Sample analyses lost (--*)

i. "Skimmed Cake" is the normal sludge cake discharged by the unit

j. "Bowl Cake" is the residual cake in the bowl that is periodically removed from centrifuge

k. "Combined Flow" represents analyses of the combined volumes of waste activated sludge and pressurized flow

m. Two (2) dilutions of raw sludge feed were tested during each run; pilot plant final effluent was used for dilution

n. Sample Nos. T-3C and T-9C represents the use of Walker Process Equipment's Pilot Poly-Thickener Unit (7-1/2" dia. x 14' SWD). Sample No. T-8C represents use of the research project's pilot settling column (3-1/2" dia. x 12' SWD).

p. O.P. values are soluble orthophosphorus as P

q. T.P. values are total soluble phosphorus as P

SOLIDS HANDLING STUDIES - CHEMICAL ADMIXTURES

Unit Process	Sample Number	Chemical Admixture	Chemical Feed Rates
Centrifugation			
Sharples Equipment Div.		Reten 210	Unavailable
Dissolved Air Flotation			
Rex Chainbelt, Inc.	Rex 35C	Dow C-7	0.5 - 10 lbs./ton D.S.
	Rex 6C, 9C	Dow C-31	2 - 40 lbs./ton D.S.
	Rex 38C	Gendriv 162	5 - 20 lbs./ton D.S.
	Rex 25C	Nalco 603	15 - 40 lbs./ton D.S.
The Eimco Corp.	E-4, E-5, E-6	Dow C-31	2 - 10 mg/l based on forward flow to unit (recycle excluded)
Gravity Thickening			
Walker Process Equip.	All	Nalco 610	10 mg/l based on flow to unit
Pressure Filtration			
Beloit-Passavant Corp.	All	Fly Ash	1:1 - 3:1 by weight*
	All	Lime	0.1:1 - 0.2:1 by weight
Vacuum Filtration			
The Eimco Corp.	All	$FeCl_3$	0 - 8% , by weight
	All	Lime (as CaO)	4 - 23%, by weight
	Selected	Magnafloc 521-C	0 - 20%, by weight
Walker Process Equip.	All	$FeCl_3$	0 - 11%, by weight
	All	Lime (as $Ca(OH)_2$)	10 - 23%, by weight

* By weight means dry weight of chemical to dry weight of total solids.

SOLIDS HANDLING STUDIES

Unit Process Centrifugation

Company / Sample Source	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.	pH	BOD^b mg/1	Nutrient Anal. NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Sharples Equipment Division														
Solid Bowl Centrifuge														
Raw Feed Sludge (13:1)^f	Run 1	S,T					30148	24944	82.7	6.5		13.5	179	691
Centrate	1	S,T	S				10936	7932	72.5	11.3		57.9	106	267
Centrate	1-C^g	S,T	S				630	470	74.6	9.8		30.4	3.1	10.0
Raw Feed Sludge (13:1)	Run 2	T	S				29708	24492	82.4	6.2		173	185	664
Centrate	1E	T	S				17000	13892	81.7			167		
Cake	1S	S,T		8.1										
Centrate	2EC	T	S				340	___*^{h}		6.9	1440	119	4.5	20.9
Cake	2SC	S,T		11.0										
Centrate	3EC	T	S				380	___*		7.1	1265	115	4.4	13.8
Cake	3SC	S,T		9.9										
Centrate	4E	T	S				21610	17425	80.6					
Cake	4S	S,T		10.0										
Centrate	5EC	T	S				1870	1400	74.9	7.0	1670	132	9.1	32.8
Cake	5SC	S,T		9.2										
Centrate	6EC	T	S				2200	1670	75.9	7.0	1875	144	10.9	40.0
Cake	6SC	S,T		10.8										
Centrate	7E	T	S				10950	8760	80.0					
Cake	7S	S,T		8.1										
Centrate	8EC	T	S				330	___*		7.2	1170	109	4.2	12.5
Cake	8SC	S,T		9.4										
Centrate	9EC	T	S				1300	990	76.2	7.2	1480	126	8.0	22.9
Cake	9SC	S,T		9.0										

Unit Process Centrifugation (Continued)

Company Sample Source	Sample No.	We (a)	They (a)							pH	BOD^b mg/1	Nutrient Anal.		
				TS %	TVS %	% Vol	TSS mg/1	VSS mg/1	% Vol.			NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Fletcher Centrifuge														
Raw Feed Sludge (13:1)	FF-1	T	S				14888	12404	83.3	6.7		19.6	65.6	369
Centrate	1-E1	T	S				1292	1172	90.7	7.3	413	13.6	10.4	35.4
Skimmed Cake[i]	1-S1	T	S	7.2										
Bowl Cake[j]	1-S2	T	S	10.5										
Centrate	1-E2	T	S				1520	1220	80.3	7.1	600	14.3	12.7	42.8
Centrate	1-E3	T	S				8348	6816	81.6					
Raw Feed Sludge (13:1)	FF-2	T	S				15124	12644	83.6	6.6		22.5	75.6	341
Centrate	2-E1	T	S				904	740	81.9	7.2	338	13.9	9.6	39.8
Skimmed Cake	2-S1	T	S	8.1										
Bowl Cake	2-S2	T	S	11.3										
Raw Feed Sludge (13:1)	FF-3	T	S				15564	12960	83.3	6.5		16.4	58.6	350
Centrate	3-E1	T	S				2492	2112	84.8	7.1	900	11.4	16.5	66.0
Skimmed Cake	3-S1	T	S	6.2										
Bowl Cake	3-S2	T	S	10.2										
Raw Feed Sludge (13:1)	FF-4	T	S				17956	14924	83.1					
Centrate Composite	4-E1	T	S				1484	1152	77.6	6.7	675	7.9	9.4	31.0
Skimmed Cake	4-S1	T	S	9.8										
Bowl Cake	4-S2	T	S	13.8										
Raw Feed Sludge (13:1)	FF-5	T	S				17744	14712	82.9	7.0		18.5	7.0	304
Centrate Composite	5-E1	T	S				1564	1156	73.9	6.8	825	9.3	10.3	33.2
Skimmed Cake	5-S1	T	S	8.2										
Bowl Cake	5-S2	T	S	13.2										
Raw Feed Sludge (13:1)	FF-6	T	S				16616	13940	83.9					
Centrate Composite	6-E1	T	S				2196	1772	80.7	6.9	975	10.0	6.7	48.5
Skimmed Cake	6-S1	T	S	7.3										
Bowl Cake	6-S2	T	S	13.5										

Unit Process Dissolved Air Flotation

Company	Sample No.	We (a)	They (a)							pH	BOD[b] mg/1	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.			NH_3[c] m /1	O.P.[d] mg/1	T.P.[e] mg/1
Rex Chainbelt, Inc.														
Raw WAS Feed	Run 1	S,T					11044	9860	89.3	6.7		42.1	45.9	240
Combined Flow[k]	7						3480E	3150E	90.5					
Subnatant	7	S,T					220	200	90.9	6.8	385	29.1	5.7	10.5
Combined Flow	6-C[g]						3480E	3150E	90.5					
Subnatant	6-C[g]	S,T					124	92	74.2	7.1	310	17.3	3.9	8.1
Raw WAS Feed	Run 2	S,T					12364	10636	86.0					
Combined Flow	8	S,T					4228	3560	84.0	6.7				
Combined Flow	9-C	S,T					4028	3520	87.4	6.8				
Raw WAS Feed	Run 3	S,T					11772	10060	85.5	6.7		19.4	59.4	262
Combined Flow	20						3672E	3110E	84.7					
Subnatant	20	S,T					200	116	58.0	6.9	371	16.2	2.1	6.6
Combined Flow	25-C						3672	3110	84.7					
Subnatant	25-C	S,T					216	128	59.3	7.1	335	15.5	2.6	7.4
Pressurized Flow	Run 4	S,T					300	216	72.0	6.3	589	19.3	5.3	13.2
Raw WAS Feed	Run 4	S,T					11472	9604	83.7	6.6		12.5	39.8	240
Combined Flow	30						3701E	3126E	84.5					
Subnatant	30	S,T					320	216	67.5	6.6	305	15.0	4.0	9.8
Combined Flow	35-C						3700E	3114E	84.2					
Subnatant	35-C						172	132	76.7	6.6	340	13.2	4.3	11.5
Combined Flow	38-C						3683	3113	84.5					
Subnatant							104	80	76.9	6.9	255	12.9	3.8	8.8

SOLIDS HANDLING STUDIES

Unit Process Dissolved Air Flotation

Company	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/l	VSS mg/l	% Vol.	pH	BOD^b mg/l	Nutrient Anal. NH$_3$^{c} mg/l	O.P.^{d} mg/l	T.P.^{e} mg/l
Sample Source														
The Eimco Corporation														
Raw WAS Feed		S, T					12, 792	10,484	82.0					
Subnatant	E-1		S, T				180							
Float Concentration	E-1		S, T	3.39										
Subnatant	E-2		S, T				551							
Float Concentration	E-2		S, T	2.99										
Subnatant	E-3		S, T				224							
Float Concentration	E-3		S, T	3.77										
Subnatant	E-4C		S, T				190							
Float Concentration	E-4C		S, T	3.38										
Subnatant	E-5C		S, T				340							
Float Concentration	E-5C		S, T	3.50										
Subnatant	E-6C		S, T				241							
Float Concentration	E-6C		S, T	3.53										

SOLIDS HANDLING STUDIES

Unit Process Gravity Thickening

Company / Sample Source	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.	pH	BOD^b mg/1	Nutrient Anal. NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Dorr-Oliver, Inc.														
Raw Sludge Feed (13:1)	Run 1^m	S,T					4408	3876	87.9	7.0		18.7	20.1	78.7
Supernatant	"	S,T					210	180	85.7	7.0	264	19.1	5.4	9.2
Raw Sludge Feed (13:1)	Run 1^m	S,T					8520	7432	87.2	7.0		21.6	35.0	168
Supernatant	"	S,T					170	150	88.2	6.9	276	19.8	7.2	11.4
Raw Sludge Feed (13:1)	Run 2	S,T					4052	3408	84.1	6.9		5.0	16.6	72.1
Supernatant	"	S,T					160	128	80.0	7.0	130	1.5	1.7	51
Raw Sludge Feed (13:1)	Run 2	S,T					7772	6748	86.8	6.7		7.6	32.8	160
Supernatant	"	S,T					152	120	78.9	7.0	160	4.0	2.3	6.0
Raw Sludge Feed (13:1)	Run 3	S,T					3324	2812	84.6	7.5		7.1	18.2	44.8
Supernatant	"	S,T					142	100	70.4	7.3	75	3.6	2.3	4.2
Raw Sludge Feed (13:1)	Run 3	S,T					6516	5520	84.7	7.5		16.1	37.1	168
Supernatant	"	S,T					160	108	67.5	7.3	105	6.4	2.7	6.4
Raw Sludge Feed (13:1)	Run 4	S,T					2676	2300	85.9	7.0		5.0	9.2	45.9
Supernatant	"	S,T					136	104	76.5	7.2	60	3.9	2.3	5.1
Raw Sludge Feed (13:1)	Run 4	S,T					6104	5144	84.3	7.0		4.3	21.9	103
Supernatant	"	S,T					232	148	63.8	7.1	110	2.9	2.8	7.5

SOLIDS HANDLING STUDIES

Unit Process Gravity Thickening

Company Sample Source	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.	pH	BOD^b mg/1	Nutrient Anal. NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Eimco Corporation														
Raw Sludge Feed (13:1)	Run 1	S,T					14248	12460		6.4		29.3	50.3	240
Supernatant	"	S,T					313	227	72.5	7.0	335	20.9	10.2	18.1
Raw Sludge Feed (13:1)	Run 2	S,T					16864	14344	85.1	6.8		21.6	78.7	323
Supernatant	"	S,T					142	142		6.8	145	4.7	3.2	5.9
Raw Sludge Feed (13:1)	Run 3	S,T					14160	13228	93.4	6.7		41.4	76.9	240
Supernatant	"	S,T					276	192	69.6	6.7	240	7.6	3.6	7.6
Raw Sludge Feed (13:1)	Run 4	S,T					15068	12568	83.4	6.5		11.1	51.1	245
Supernatant	"	S,T					288	196	68.1	7.0	165	2.9	2.4	7.9

SOLIDS HANDLING STUDIES

Unit Process Gravity Thickening

Company	Sample No.	We (a)	They (a)							pH	BOD^b mg/l	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/l	VSS mg/l	% Vol.			NH$_3$^{c} mg/l	O.P.^{d} mg/l	T.P.^{e} mg/l
Walker Process Equipment														
Raw WAS Feed^n	T-3C^g	S,T					12732	10564	83.0	7.0		70.3	69.9	110
Supernatant	"	S,T					84			7.0	345	31.8	3.4	6.3
Raw WAS Feed +Fe^n	T-8C	S,T					9860	8028	81.4	6.9		22.9	61.2	179
Supernatant	"	S,T					111			7.0	68	18.9	5.0	10.7
Raw WAS Feed +Fe^n	T-9C	S,T					7708	6388	82.9	6.9		33.6	48.1	184
Supernatant	"	S,T					143	143		7.1	68	15.0	3.6	8.4

SOLIDS HANDLING STUDIES

Unit Process Heat Treatment

Company / Sample Source	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/l	VSS mg/l	% Vol.	pH	BOD^b mg/l	Nutrient Anal. NH$_3$^{c} mg/l	Nutrient Anal. O.P.^{d} mg/l	Nutrient Anal. T.P.^{e} mg/l
Dorr-Oliver, Inc.														
Raw Sludge Feed (13:1)	3	S,T					30840	26368		6.4		187	238	756
Raw Sludge as Tested	1		S,T				30710	26270		5.4				
Cooked Sludge	1-A		S,T				19920	16400	82.3	5.0	7950			
Cooked Sludge	1-B		S,T				17050	14970	87.8	4.9	8520			
Cooked Sludge	1-C		S,T				17680	12990	73.4	5.0	8210			
Decant	"	T	S				16948	12844	75.8	5.4	12600	421	68.2	140
Cooked Sludge	1-D		S,T				17090	12390	72.5	5.0	8000			
Decant	"	T	S				8164	6312	77.3	5.4	13200	506	74.7	153
Raw Sludge Feed (13:1)	2	S,T					30580	25472	83.3	6.8		80.0	190	511
Raw Sludge as Tested	2		S,T				32660	27100	83.0		2809			
Cooked Sludge	2-A		S,T				18660	13840	74.2		8470			
Decant	"	T	S				180	60	33.0	5.0	11400	355	13.1	61.2

SOLIDS HANDLING STUDIES

Unit Process Heat Treatment

Company Sample Source	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.	pH	BOD^b mg/1	Nutrient Anal. NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
BSP Corporation														
Raw Sludge Feed (13:1)	1-2	S,T					30840	26368	85.5	6.4		187	238	756
Raw Sludge as Tested	1-2		S,T	3.11	2.54	81.8				5.9				
Cooked Sludge	1-2		S,T	3.11	2.07	66.5				5.4				
Decant	1-2		S,T				194	174	89.7	5.4	5330	305	36.5^p	24.5^q
Decant Sludge	1-2		S,T	7.75	4.92	63.5								
Filtrate	1-2		S,T				266	218	82.0	5.4	6340	343	48.9^p	39.1^q
Cake	1-2		S,T	26.5	17.6	66.5								
Raw Sludge Feed (13:1)	3	S,T					29392	24836	84.5	6.4		155	119	642
Raw Sludge as Tested	3		S,T	3.30	2.37	71.7				6.4	16000	98	7.2^p	9.5^q
Cooked Sludge	3		S,T	1.58	1.09	69.0				5.7	7000	154	24.3^p	18.3^q
Decant	3		S,T				106	68	64.2	5.6	4000	162	24.3^p	18.1^q
Decant Sludge	3		S,T	4.19	2.51	60.0								
Filtrate	3		S,T				508	336	66.1	5.6	5500	146	74.5^p	55.5^q
Cake	3		S,T	25.0										

SOLIDS HANDLING STUDIES

Unit Process Heat Treatment

Company	Sample No.	We (a)	They (a)							pH	BOD^b mg/1	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.			NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Zimpro, Inc.														
Raw Sludge Feed (13:1)	B-2	S,T					34416	29632	86.1	5.9		122	192	691
Raw Sludge as Tested	#36		S,T	3.71	3.07	82.7				5.9		370	11	700
Cooked Sludge	"		S,T	2.68	2.15	80.2	13400	9200	68.7			440		520
Decant	"		S,T	1.53	1.38	90.2	300	300			7900	470		50
Decant Sludge	"		S,T	7.02	5.12	72.9	59800	41600	69.6					
Filtrate	"		S,T	1.36	1.24	91.2	300E	300E			7500	450	7	60
Cake	"		S,T	38.0	26.9	70.8								
Raw Sludge Feed (13:1)	B-3	S,T					33104	28412	85.8	6.0		129	131	673
Raw Sludge as Tested	#37		S,T	3.46	2.87	82.9				6.2		410	14	570
Cooked Sludge	"		S,T	2.92	2.40	82.2	17100	12900	75.4			390		460
Decant	"		S,T	1.44	1.30	90.3	300	300			7090E			
Decant Sludge	"		S,T	6.31	4.95	78.4	52800	40000	75.8					
Filtrate	"		S,T	1.25	1.14	91.2				5.8	6560E	400	9	70
Cake	"		S,T	35.0	26.6	76.1								
Raw Sludge Feed (13:1)	B-2	S,T					30996	25504	82.3	6.7		146	214	489
Raw Sludge as Tested	#41		S,T	3.21	2.59	80.7				5.4		400	22	320
Cooked Sludge	"		S,T	2.08	1.64	78.8	11300	8100	71.7			330		310
Decant	"													
Decant Sludge	"		S,T	7.61	5.35	70.3	76400	54700	71.6					
Filtrate	"		S,T	.99	.90	90.9	1970E	1467E	74.5	5.7	5700	350	9	30
Cake	"		S,T	32.8	22.3	68.0								
Raw Sludge Feed (13:1)	B-3	S,T					30580	25472	83.3	6.8		80.0	190	511
Raw Sludge as Tested	#42		S,T	3.34	2.68	80.2				6.1		360	97	360
Cooked Sludge	"		S,T	1.45	1.13	77.9	7400	4800	64.9			260		150
Decant	"													
Decant Sludge	"		S,T	5.89	4.14	70.3	53450	36600	68.5					
Filtrate	"		S,T	0.73	0.66	90.4	890E	530E	59.6	5.4	4300	280	8	20
Cake	"		S,T	34.7	23.6	67.9								

SOLIDS HANDLING STUDIES

Unit Process Low Pressure Oxidation

Company	Sample No.	We (a)	They (a)									Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.	pH	BOD^b mg/1	NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Zimpro, Inc.														
WAS & P.C. Mixture (16.6:1)	B-1	S,T					30588	25836	84.5	6.2		122	188	656
Raw Sludge as Tested	#35		S,T	3.18	2.60					6.0		470	13	220
Cooked Sludge	"		S,T	2.31	1.82		11400	7900				470		200
Decant Liquor	"		S,T	1.24	1.08		200	200		4.7	6000	520		30
Decant Sludge	"		S,T	6.74	4.81		58270	40070						
Filtrate Liquor	"		S,T	1.19	1.04		350E	350E		5.0	5700	480	18	30
Cake	"		S,T	33.4		69.4								
WAS & P.C. Mixture (13:1)	B-1	S,T					29994	24624	82.2	6.5		73.2	114	236
Raw Sludge as Tested	#40		S,T	3.21	2.56					5.2		320	31	370
Cooked Sludge	"		S,T	2.09	1.59		10400	6900				450		290
Decant Liquor	"		S,T	1.03	0.92					4.6	5700	470		30
Decant Sludge	"		S,T	7.66	5.36		67800	46300						
Filtrate Liquor	"		S,T	1.06	0.91		730E	730E		4.8	5600	450	11	30
Cake	"		S,T	31.7		67.7								

SOLIDS HANDLING STUDIES

Unit Process Pressure Filtration

Company	Sample No.	We (a)	They (a)							pH	BOD^b mg/1	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.			NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Beloit-Passavant Corp.														
Raw Sludge Feed (13:1)	Prelim	S,T					34304	29304	85.4			230	245	752
Filtrate	"-C8	T	S				73	20	27.4	12.1	2310	184	0.1	8.7
Cake	"-C	T	S	40.8	16.9	41.5								
Raw Sludge Feed (13:1)	1	S,T					32084	27592	86.0	6.4		104	175	791
Filtrate	1-C	T	S				7	--*			600	50	0.3	2.2
Cake	R1C	T	S	33.5	13.0	38.7								
Filtrate	2-C	T	S				198	16	8.1	8.9	1005	76	0.1	5.5
Cake	R2C	T	S	51.1	17.3	33.8								
Filtrate	3-C	T	S				566	109	19.3	7.3	1230	62	2.2	16.4
Cake	R3C	T	S	42.7	16.5	38.7								
Filtrate	4-C	T	S				24	20	83.3		945	72	0.6	4.7
Cake	R4C	T	S	29.4	12.9	44.0								
Filtrate	5-C	T	S				13	11	84.6	7.9	1020	75	0.9	4.5
Cake	R5C	T	S	40.7	13.7	33.7								
Filtrate	6-C	T	S				54	20	37.0	7.9	930	71	0.8	5.7
Cake	R6C	T	S	30.0	12.6	42.1								
Raw Sludge Feed (13:1)	1	S,T					28688	24188	84.3	6.1		118E	139	599
Filtrate	1-C	T	S				23	18	78.3	8.1	908	61	0.2	1.4
Cake	R1C	T	S	50.0	14.8	29.6								
Filtrate	2-C	T	S				28	22	78.6	7.4	1080	78	0.6	1.9
Cake	R2C	T	S	46.9	14.6	31.2								
Filtrate	3-C	T	S				46	42	91.3	7.9	1095	71	0.4	1.7
Cake	R3C	T	S	48.0	16.4	34.2								
Filtrate	4-C	T	S				61	48	78.7	7.5	1005	67	1.1	3.6

SOLIDS HANDLING STUDIES

Unit Process Vacuum Filtration (Raw Sludge)

Company	Sample No.	We (a)	They (a)							pH	BOD^b mg/1	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.			NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Eimco Corporation														
Raw Sludge Feed (13:1)	Run 1	S,T					22280	18940	85.0	6.0		121	94	410
Filtrate	T-6C^g	S,T					1053	560	53.2	11.7	990	77.3	2.8	15.3
Cake	"	S,T		13.0										
Filtrate	T-7C	S,T					1240	720	58.1	11.7	1080	66.9	3.5	18.1
Cake	"	S,T		14.6										
Raw Sludge Feed (13:1)	Run 2	S,T					34188	28504	83.4	6.0		52.2	153	586
Filtrate	T-1C	S,T					376	220	58.5	12.1	1020	36.7	1.0	6.6
Cake	"	S,T		17.2										
Filtrate	T-3C	S,T					372	200	53.8	12.1	930	37.4	1.4	5.1
Cake	"	S,T		16.5										
Filtrate	T-4C	S,T					472	296	62.7	12.1	870	38.5	1.4	6.3
Cake	"	S,T		15.5										
Filtrate	T-5C	S,T					496	276	55.6	12.1	960	40.3	1.6	7.6
Cake	"	S,T		19.0										
Filtrate	T-6C	S,T					288	130	45.1	12.1	990	28.1	0.8	3.6
Cake	"	S,T		15.3										
Raw Sludge Feed (13:1)	Run 3	S,T					32136	27404	85.3	6.6		69.1	124	581
Filtrate	T-1C	S,T					300	156	52.0	12.3	1575	76.6	0.8	3.5
Cake	"	S,T		14.0										
Filtrate	T-3C	S,T					306	148	48.4	12.2	1050	61.5	0.8	4.5
Cake	"	S,T		12.7										
Filtrate	T-4C	S,T					360	164	45.6	11.9	900	50.7	1.0	4.4
Cake	"	S,T		14.4										
Filtrate	T-5C	S,T					472	384	81.4	7.0	1020	96.4	7.0	17.9
Cake	"	S,T		11.4										
Raw Sludge Feed (13:1)	Run 4	S,T					29840	24836	83.2	7.2		168	50.3	586
Filtrate	T-1C	S,T					408	180	44.1	11.9	960	58.6	0.9	6.1
Cake	"	S,T		15.3										
Filtrate	T-2C	S,T					900	488	54.2	12.0	1050	59.6	4.4	16.8
Cake	"	S,T		17.0										
Filtrate	T-3C	S,T					736	380	51.6	12.0	1110	51.1	2.7	11.6
Cake	"	S,T		14.7										

SOLIDS HANDLING STUDIES

Unit Process Vacuum Filtration (continued)

Company	Sample No.	We (a)	They (a)							pH	BOD^b mg/1	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.			NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Eimco Corporation	Run 4													
Filtrate	T-4C	S,T					568	224	39.4	11.6	960	51.4	2.0	6.1
Cake	"	S,T		15.4										
Filtrate	T-5C	S,T					580	272	46.9	11.8	900	50.0	2.3	7.4
Cake	"	S,T		16.6										
Filtrate	T-6C	S,T					524	240	45.8	11.7	930	65.7	3.4	12.0
Cake	"	S,T		15.4										

SOLIDS HANDLING STUDIES

Unit Process Vacuum Filtration

Company Sample Source	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/l	VSS mg/l	% Vol.	pH	BOD^b mg/l	Nutrient Anal. NH$_3$^{c} mg/l	Nutrient Anal. O.P.^{d} mg/l	Nutrient Anal. T.P.^{e} mg/l
Walker Process Equipment														
Raw Sludge Feed (13:1)	5-WI	T	S				36680	23748	64.7	9.7				
Filtrate	5-WC8	T	S				124	60	48.4	10.5	1035	59.6	0.6	8.6
Cake	"	T	S	14.4	10.4	72.1								
Cake	3-WC	T	S	15.7	11.5	73.5								
Cake	7-WC	T	S	12.3	9.1	73.9								

SOLIDS HANDLING STUDIES

Unit Process FE Microscreening

Company / Sample Source	Sample No.	We (a)	They (a)	TS %	TVS %	% Vol.	TSS mg/l	VSS mg/l	% Vol.	pH	BOD[b] mg/l	Nutrient Anal. NH_3[c] mg/l	O.P.[d] mg/l	T.P.[e] mg/l
Beloit-Passavant Corp.														
Raw Final Effluent	BP-1	S, T					76	56	73.7					
10 M Filtrate	BP-1AB	S, T					45	33	73.3					
3 M Filtrate	BP-5AB	S, T					42	30	71.4					
Raw Final Effluent	BP-2	S, T					95	72	75.8					
10 M Filtrate	BP-2AB	S, T					65	48	73.8					
3 M Filtrate	BP-6AB	S, T					57	41	71.9					
Raw Final Effluent	BP-3	S, T					52	49	94.2					
10 M Filtrate	BP-3B	S, T					18	--*						
3 M Filtrate	BP-7AB	S, T					11	--*						
Raw Final Effluent	BP-4	S, T					20	15	75.0					
10 M Filtrate	BP-4AB	S, T					15	9	60.0					
3 M Filtrate	BP-8AB	S, T					2	--*						
Note: M = Micron														

Unit Process FE Microstraining

Company	Sample No.	We (a)	They (a)							pH	BOD^b mg/1	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/1	VSS mg/1	% Vol.			NH$_3$^{c} mg/1	O.P.^{d} mg/1	T.P.^{e} mg/1
Crane-Glenfield, Inc.														
Raw Final Effluent	A	T	S				94	84	89.4	7.0	138			
Filtrate	A-12	T	S				68	66	97.1	7.2	41			
Raw Final Effluent	B	T	S				116	108	93.1	7.4	86			
Filtrate	B-12	T	S				84	82	97.6	7.4	39			
Raw Final Effluent	C	T	S				62	--*		7.4	78			
Filtrate	C-12	T	S				27	--*		7.4	69			
Raw Final Effluent	D	T	S				27	--*		7.2	18			
Filtrate	D-12	T	S				7	--*		7.4	13			

SOLIDS HANDLING STUDIES

Unit Process FE Microscreening

Company	Sample No.	We (a)	They (a)							pH	BOD^b mg/l	Nutrient Anal.		
Sample Source				TS %	TVS %	% Vol.	TSS mg/l	VSS mg/l	% Vol.			NH$_3$^{c} mg/l	O.P.^{d} mg/l	T.P.^{e} mg/l
Southwestern Engr. Co.														
Raw Final Effluent	A-D	T	S				42	---*		7.2	59			
Filtrate	100M	T	S				29	---*			58			
Filtrate	200M	T	S				30	---*			52			
Filtrate	325M	T	S				32	---*			54			
Note: M = Mesh														

APPENDIX F

FULL-SCALE DESIGN PARAMETERS

DESIGN PARAMETERS DEVELOPED FROM LABORATORY DATA - Part 1

DESIGN PARAMETER	February, 1969			July, 1969		February, 1970
	C	CS	K	CS	K	CS
1. PRIMARY TREATMENT						
A. Influent: Average Flow	MSD + All Mills	Same	Same	MSD + All Mills	Same	MSD + All Mills
Storm Flow						MSD Only
B. Design Flow: Avg, Peak; MGD	44.25;	Same	Same	51.1;	Same	53.85; 120.0
C. Surface Area: Square Feet	56,250	Same	Same	85,200	Same	89,700
D. Sidewater Depth: Feet				10.0	Same	12.0
E. Overflow Rate: Avg, Peak; GPD/SF	800;	Same	Same	600;	Same	600; 1340
F. Detention Time: Avg, Peak; Hours		. . .		3.0;	Same	3.6; 1.6
G. Efficiency:						
1) PI-BOD, PE-BOD; 10^3/Lbs/D	184.5; 166.5	Same	Same	213.0; 213.0	Same	229.4; 215.6
% BOD Removal	10.0	Same	Same	0.0	Same	6.0
2) PI-TSS, PE-TSS; 10^3/Lbs/D	89.2; 51.1	Same	Same	75.0; 60.0	Same	78.2; 57.1
% TSS Removal	42.0	Same	Same	20.0	Same	27.0
H. Primary Clarifier Sludge	Primary + WAS	Same	Same	Primary Only	Same	Primary Only
1) Volume: Avg; GPD	252,000	396,000	396,000	32,800	Same	46,000
2) Total Suspended Solids: mg/l	50,000	50,000	50,000	55,000	Same	55,000
% Volatile Suspended Solids	85.6	86.8	80.9	83.0	Same	83.7
2. BIO-TREATMENT SYSTEM						
A. Influent: Average Flow	Primary Eff.	Same	Same	Primary Eff.	Same	Primary Eff.
Storm Flow						PE. Less Bypass + Mills
B. Design Flow: Avg, Max; MGD	44.25;	Same	Same	51.1;	Same	53.85; 94.0
C. Process Volumes: MG						
1) Sludge Reaeration or Nitrification	N/A	5.8	5.1	5.2	5.1	6.2
2) Contact Aeration	29.5	8.2	12.3	10.4	15.6	10.8

DESIGN PARAMETERS DEVELOPED FROM LABORATORY DATA - Part 2

DESIGN PARAMETER	February, 1969			July, 1969		February, 1970
	C	CS	K	CS	K	CS
D. Process Detention Time, Hours						
1) Sludge Reaeration		4.0	24.0	3.5	24.0	4.1
Flow Basis (Rn = 20% R)	N/A	Avg R	Avg R_n + D	Avg R	Avg R_n + D	Avg R
2) Contact Aeration	8.0	2.5	4.3	2.9	5.0	2.9
Flow Basis	Avg R + Q	Avg R + Q	Avg R + D + Q	Avg R + Q	Avg R + D + Q	Avg R + Q
E. Mixed Liquor Solids: mg/l						
1) Reaeration: TSS, VSS	N/A	9100; 8000	12500; 10000	10000; 8600	15000; 12300	10000; 8600
2) Contact: TSS, VSS	3450; 3000	3980; 3500	4375; 3500	4070; 3500	4510; 3700	4070; 3500
F. Recirculation Capacity:						
1) R/Q Ratio	1.00	0.78	0.54	0.69	0.43	0.69
2) Average R @ Design Q: MGD	44.25	34.5	23.9	35.6	22.3	36.8
Max R: MGD						
G. Oxygen Requirements:						
1) Alpha (α) Factors: Avg	0.75 (Est.)	Same	Same	R ; C 0.93; 0.86	N ; C 0.70; 0.83	R ; C 0.72; 0.78
2) Beta (β) Factors: Avg	0.90 (Est.)	Same	Same	0.91; 0.92	0.83; 0.87	0.84; 0.91
3) Lbs O_2 Required/Lb BOD Removed @ °C	2.54 @ 20	1.87 @ 20	2.04 @ 20	1.21 @ 20	1.59 @ 20	1.62 @ 26.6
4) Lbs O_2 Required/Day @ °C	378,000 @ 20	279,000 @ 20	304,000 @ 20	239,000 @ 20	334,000 @ 20	327,000 @ 26.6
H. Standard Parameter Values:						
1) F/M Ratio: Lbs BOD/Lb MLVSS	0.23	0.27	0.21	0.32	0.21*	0.29
2) Volumetric Loading: Lbs BOD/1000 CF/Day	42	89	72	102	77*	94

* Exclusive of Digester Supernatant

DESIGN PARAMETERS DEVELOPED FROM LABORATORY DATA - Part 3

DESIGN PARAMETER	February, 1969			July, 1969		February, 1970
	C	CS	K	CS	K	CS
J. Sludge Production:						
1) Lbs TSS Produced/Lb BOD Removed	0.45	0.70	0.85	0.65	0.40**	0.65
2) WAS Volume: MGD	1.17	1.38	1.22	1.55	1.15	1.57
3) Total Suspended Solids: mg/l	6,900	9,100	12,500	10,000	15,000	10,000
% Volatile Suspended Solids	87.0	88.0	80.0	86.0	82.0	86.0
3. FINAL CLARIFICATION						
A. Design Flow: Avg. Max; MGD	44.25;	Same	Same	51.1;	Same	53.85; 94.0
B. Overflow Rate: Avg. Max; GPD/SF	333;	433;	466;	400; 700	Same	400; 700
C. Surface Area: Square Feet	136,000	102,000	94,800	130,000	Same	135,000
D. Surface Area Required For Thickening: SF	136,500	85,300	76,400	93,500	115,000	96,800
E. Solids Loading Rate at Design Surface Area: Lb TSS/SF/Day	18.7;	25.6;	26.3;	22.8;	21.5;	23.0; 40.0
F. Sidewater Depth: Feet	10.0	Same	Same	10.0	Same	12.0
G. Detention Time: Avg. Max; Hours	5.5;	4.1;	3.8;	4.5;	Same	5.4;
4. OVERALL PLANT EFFICIENCIES						
A. PI-BOD; FE-BOD, Lb/Day	184,500; 18,450	Same	Same	213,000; 12,950	213,000; 14,100	229,400; 13,470
% BOD Removal @ °C	90 @ 20	Same	Same	94 @ 20	93 @ 20	94 @ 20
5. ANAEROBIC DIGESTION						
A. Desired:						
1) Detention Time: Days		--	20.0		20.0	
2) Volumetric Loading: Lbs VSS/CF/Day			0.1		0.1	
B. Calculated:						
1) Detention Time: Days			25.3		21.6	
2) Volumetric Loading: Lbs VSS/CF/Day			0.1		0.1	
3) Total Required Volume: CF			864,000		1,045,000	

** Includes Digester Supernatant Solids

DESIGN PARAMETERS DEVELOPED FROM LABORATORY DATA - Part 4

DESIGN PARAMETER	February, 1969			July, 1969		February, 1970
	C	CS	K	CS	K	CS
C. Flow: MGD						
1) Raw Sludge Feed			0.256		0.382	
2) Digested Sludge			0.051		0.074	
3) Supernatant Liquor Return To Nitrification Tank			0.205		0.308	
6. ANCILLARY FACILITIES						
A. Chlorination:						
1) PE-Sulfide ($S^=$) Control			Not Required			
a. Feed Time						
b. Feed Rate: mg/l; MGD	30 ; 44.25	Same				
2) RAS-Bulking Control			Not Required			
a. Feed Time				Continuous	Continuous	Continuous
b. Feed Rate: mg/l ; MGD	30 ; 44.25	30; 34.5		10; 35.6	10; 22.3	10-30; 36.8
3) FE-Disinfection	Not Considered For This Estimate					
a. Feed Time				Continuous	Continuous	Continuous
b. Feed Rate: mg/l; MGD						
Average				13.5; 51.1	Same	10; 53.85
Maximum						15; 143.85
B. Nutrients:						
1) BOD:N:P Ratio	100:5:1	Same		100:5:1		100:5:0.5
2) Nitrogen (Chemical Used)	Anhydrous NH_3	Same	Digester Supt.	Anhydrous NH_3	Digester Supt.	Anhydrous NH_3
a. Feed Rate: Avg, Max; Lbs/D as N	1170;	Same		1490;		2800;
3) Phosphorus (Chemical Used)	Phosphoric Acid	Same	Digester Supt.	Phosphoric Acid	Digester Supt.	Phosphoric Acid
a. Feed Rate: Avg, Max; Lbs/D as P	1080;	Same		1385;		431;

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ALTERNATE DESIGN PARAMETERS USED IN COST ESTIMATES - Part 1

DESIGN PARAMETER	February, 1969			July, 1969		February, 1970
	C	CS	K	CS	K	CS
1. PRIMARY TREATMENT						
A. Influent: Average Flow						MSD Only
Storm Flow	MSD + All Mills	Same	Same	MSD + Mill 3	Same	
B. Design Flow: Avg, Peak; MGD	; 100.4	Same	Same	; 136.7	Same	30.0;
C. Surface Area: Square Feet						38,000
D. Sidewater Depth: Feet	12.0	Same	Same	12.0	Same	
E. Overflow Rate: Avg, Peak; GPD/SF	; 1750	Same	Same	; 1600	Same	790; 3160
F. Detention Time: Avg, Peak; Hours	2.8; 1.2	Same	Same	3.6; 1.3	Same	2.7; 0.7
G. Efficiency:						
1) PI-BOD, PE-BOD; 10^3/Lbs/D						59.0; 39.5
% BOD Removal						33.0
2) PI-TSS, PE-TSS; 10^3/Lbs/D						46.0; 18.4
% TSS Removal						60.0
H. Primary Clarifier Sludge						
1) Volume: Avg; GPD						60,300
2. BIO-TREATMENT SYSTEM						
A. Influent: Average Flow						PE + All Mills
Storm Flow	Primary Eff.	Same	Same	PE, less bypass, + Mills 1, 2, 4	Same	
B. Design Flow: Avg, Max; MGD	; 100.4	Same	Same	; 91.2		
F. Recirculation Capacity:						
1) R/Q Ratio						
2) Average R @ Design Q: MGD			Rn; Rc 4.8; 19.1		Rn; Rc 4.4; 17.5	
Max R: MGD	56.5	45.0	7.2; 45.0	91.2	7.0; 84.2	94.0

ALTERNATE DESIGN PARAMETERS USED IN COST ESTIMATES - Part 2

DESIGN PARAMETER	February, 1969			July, 1969		February, 1970
	C	CS	K	CS	K	CS
3. FINAL CLARIFICATION						
A. Design Flow: Avg. Max; MGD	; 100.4	Same	Same	; 91.2	Same	
B. Overflow Rate: Avg. Max; GPD/SF	; 730	; 950	; 1020			
F. Sidewater Depth: Feet	12.0	Same	Same	12.0	Same	15.0
6. ANCILLARY FACILITIES						
A. Chlorination:						
1) PE-Sulfide ($S^=$) Control						
a. Feed Time	Continuous	20%		20%	Same	20%
b. Feed Rate: mg/l; MGD	30; 100.4	Same		30; 51.1	Same	30; 53.85
2) RAS-Bulking Control						
a. Feed Time	Continuous	20%			20%	
b. Feed Rate: mg/l; MGD	30; 56.5	30; 45.0		30; 35.0	30; 21.9	30; 36.8
3) FE-Disinfection						
b. Feed Rate: mg/l; MGD						
Maximum				20; 150.0	Same	15; 149.85
B. Nutrients:						
1) BOD:N:P Ratio					100:X:1	
2) Nitrogen (Chemical Used)						
a. Feed Rate: Avg. Max; Lbs/Das N	; 1675	Same		; 2980		; 5610
3) Phosphorus (Chemical Used)						
a. Feed Rate: Avg. Max; Lbs/Das P	; 1545	Same		; 2770		; 862

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PARAMETERS FOR CAPITAL AND OPERATING COST ESTIMATES

Design	PHASE II			PHASE III			PHASE IV		
Year	1980			1983			1983		
Source	Flow MGD	BOD TON/D	TSS TON/D	Flow MGD	BOD TON/D	TSS TON/D	Flow MGD	BOD TON/D	TSS TON/D
Mill 1	4.0	15.0	2.5	5.0	30.0	5.0	5.0	30.0	5.0
Mill 2	5.0	20.0	3.0	5.0	15.0	2.0	5.0	15.0	2.0
Mill 3	7.0	20.5	5.2	10.5	25.0	5.0	13.25	33.2	6.6
Mill 4	1.25	7.75	1.5	0.6	7.0	2.5	0.6	7.0	2.5
Metro	27.0	29.0	32.4	30.0	29.5	23.0	30.0	29.5	23.0
Total	44.25	92.25	44.6	51.1	106.5	37.5	53.85	114.7	39.1

DESIGN SCALE-UP FACTORS

Design Parameter	PHASE II			PHASE III		PHASE IV
	C	CS	K	CS	K	CS
Peak Flow	Metro, M3-250% M1, 2, 4 --150%	Same	Same	Metro-412% Mills -125%	Same	Metro - 400% Mills - 125%
Primary Clarifier Sludge Volume	150%	Same	Same	150%	Same	140%
Recirculation	R/Q_a = 1.25	R/Q_a=1.0	R_n=150% R_c/Q_a=1.0	R/Q_m=1.0	R/Q_m=1.0	R/Q_m=1.0
O_2 Supply	150%	Same	Same	150%	Same	170%
WAS Volume	25% Q_a	Same	Same	25%Q_a	Same	25% Q_a
Digested Sludge	----	-----	150%	----	150%	----
Dig. Sup. Return	----	-----	125%	----	125%	----
Nutrient Feed: N and P	140%	140%	----	200%	----	200%

Q_a = Q average; Q_m = Q maximum

ABBREVIATIONS

add.------ added
BOD------ Five-day biochemical oxygen demand
BOD:N:P-- biochemical oxygen demand to nitrogen (as N) to phosphorus (as P) ratio, by weight
C--------- conventional process
cap.------ capacity
CF--------cubic feet
cf/lb------cubic feet per pound
COD------ chemical oxygen demand
conc.----- concentration
CS--------contact stabilization
D.--------digester supernatant
dc/dt------rate of change of concentration with respect to time -- oxygen uptake studies
Dest.----- destroyed
Dig. sup.--digester supernatant
D.O.----- dissolved oxygen
D.S.------dried solids
D_t-------- detention time
eff.-------effluent
F-BOD----biochemical oxygen demand of sample filtered through Whatman #5 filter paper
FC--------final clarifier
FE--------final effluent
F.I.------ filterability index
F/M------ food to microorganism ratio; pounds of BOD daily fed to the aeration tanks divided by the pounds of volatile suspended solids under aeration in the contact and reaeration sections
inf.-------influent
K---------Kraus
lbs/1000 CF/day - pounds per 1000 cubic feet per day
lbs/D as N-pounds per day as nitrogen
lbs/D as P-pounds per day as phosphorous
Lbs TSS/SF/Day - pounds of total suspended solids per square foot per day
Lbs VSS/CF/Day - pounds of volatile suspended solids per cubic foot per day
L/D-------liters per day
mg/gm----milligrams per gram
mg/l O_2/MLVSS/hr. - milligrams per liter of oxygen per milligram of mixed liquor volatile suspended solids per hour
M.L.----- mixed liquor - the mixture of biological organisms and liquor undergoing aeration in the aeration tanks
MLTSS----mixed liquor total suspended solids

ABBREVIATIONS (Cont'd)

MLVSS----mixed liquor volatile suspended solids
mu. ------ millimicrons
N.A.----- no analysis
O.R.------overflow rate
P---------phosphorous
PE--------primary effluent
PEF------ primary effluent fortified - PE after nutrient addition
Phos O+C as P - ortho plus condensed phosphorous as P
PI --------primary influent
PP-PE----pilot plant primary effluent
Q---------quantity of raw sewage to be treated, = Q_f
Q_a--------Q average
Q_f-------- Q forward, = Q
Q_m------- Q minimum
R---------quantity of return activated sludge
RAS------ return activated sludge
RAS-$S^=$--- sulfide ion concentration in return activated sludge
R_c--------quantity of RAS returned to contact section of process
Reaer-----reaeration
R_n--------quantity of RAS returned to nitrifying section of process
R/Q------ ratio of return activated sludge divided by total forward flow
SA--------step aeration
Sa·t------ MLVSS concentration (mg/l) in contact section times the detention time (hours) in the contact section
S.D.------standard deviation
SFR-------specific filtration resistance
S.U.------standard units
sup.------ supernatant
SVI------- sludge volume index
SWD------ sidewater depth
T---------time
TC------- total carbon
T_o--------time at start of experiment
T.O.------total organic nitrogen
TRC------ total residual chlorine
TS--------total solids
TSS-------total suspended solids
U-BOD----BOD of unfiltered sample
ug-------- micrograms
vol.------ volume
vol. A----- volatile acid
VS/1000 CF/D - pounds of volatile solids added per 1000 cubic feet per day
VSS-------volatile suspended solids
WAS------ waste activated sludge
# ---------pounds

1 Accession Number **W**	2 Subject Field & Group 05D	**SELECTED WATER RESOURCES ABSTRACTS** **INPUT TRANSACTION FORM**

5 Organization

The Green Bay Metropolitan Sewerage District
Green Bay, Wisconsin

6 Title Joint Treatment of Municipal Sewerage and Pulp Mill Effluents

10 Author(s) Voelkel, K. G. Deering, R. W. Wilms, L. R.	16 Project Designation Grant #WPRD 60-01-67 (Program #12130 EDX) 21 Note

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Pulp Wastes, Municipal Wastes, Waste Treatment, Activated Sludge, Pilot Plant, Sludge Disposal, Capital Costs.

25 Identifiers (Starred First)

27 Abstract

The influent from the Green Bay Metropolitan Sewerage District was treated in combination with the weak effluents from pulping sections of four local paper mills, American Can Company, Charmin Paper Products Company, Fort Howard Paper Company and Green Bay Packaging, Inc. Four activated sludge processes (conventional, step aeration, contact stabilization, and Kraus) were studied in parallel using 1-gpm pilot plants. Contact stabilization was selected as the most promising process and units were operated for five months to obtain refined design and operating parameters for a full-scale treatment plant. Initially, the pilot plants became infested with filamentous organisms identified as the bacterial genus Thiothrix. Chlorination of the return activated sludge successfully controlled the growth of these organisms. It was also necessary to add nutrients to achieve the desired BOD:N:P ratios.

The operation of the pilot plant units during the last study phase gave BOD removals of 91% and TSS removals of 78%. Extensive solids-handling unit process studies were conducted at the pilot plant site and in the cooperating manufacturer's laboratories. The capital costs to the individual participants, based on becoming a part of the joint venture or providing separate facilities, are presented. American Can Company and Charmin Paper Products Company are joining with the Green Bay Metropolitan Sewerage District in a joint treatment plant program.

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